The Internal Wiring of Buildings

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The Internal Wiring of Buildings

By H.enry M.eredith LEAF
A.M.Inst.C.E : M.I.M.E

ILLUSTRATED

THIRD EDITION

Revised and enlarged with a Chapter on Electricity Meters and the new Rules for Wiring of the Institution of Electrical Engineers. The Phœnix Fire Office and The Westminster Electric Supply Corporation

LONDON:
ARCHIBALD CONSTABLE & CO. Ltd
10 Orange Street, Leicester Square, W.C
1907

BUTLER & TANNER,
THE SELWOOD PRINTING WORK
FROME, AND LONDON.

NOTE TO FIRST EDITION

In the preparation of this book I have been greatly assisted by the following firms, who have kindly placed much useful information at my disposal:—

Messrs. W. T. Glover & Co., Ltd.
The General Electric Co., Ltd.
Messrs. Veritys, Ltd.
Messrs. Mavor & Coulson, Ltd.
The Simplex Wiring Co., Ltd.

and Mr. Musgrave Heaphy, who has kindly allowed me to incorporate the rules of the Phœnix Fire Office.

H. M. LEAF.

November, 1898.

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CHAPTER I

Introduction

ELECTRIC energy is now so universally adopted for lighting, heating, transmission of power and other purposes, that insulated wires or cables (as they are often called) for conveying the current are now fixed in most buildings of any importance. The conditions under which these conductors have to perform their part of carrying the current vary within very wide limits, and it is the object of this treatise to describe the various means of fixing the wires to suit the different conditions under which the current is likely to be employed. The science of fitting up a suitable system of conductors, or "wiring," as it is termed, is not at the present time an exact science, but is rapidly becoming so. Among engineers there are several rival methods of wiring in use, and many discussions have taken place in technical journals, and at the meetings of engineering societies, on the subject of the relative advantages of concentric wiring, wood casing, and systems of iron and other tubing. Each system has merits for special purposes. Generally speaking no one system can be said to be universally better than another, provided always that due care is

taken in fixing the conductors. It has been said with truth that it is better to have an installation consisting of inferior cables and materials, well and carefully fixed, than one in which, although better materials are used, sufficient care has not been exercised in fixing and jointing.

By far the greater number of wiring installations are carried out in buildings in which the current is taken from central stations, so, unless mention is made to the contrary, it is assumed in this book that the current is obtained in this manner, and that it is direct, and not alternating in character.

It is impossible to give a description of the nature of electricity in a treatise on wiring. Those who wish to understand how it is that the so-called lines of force in the ether can give rise to electric currents when cut by conductors should consult Dr. Oliver Lodges' *Modern Views of Electricity.* In this book the production of electric currents is explained by mechanical analogies, and the reader is enabled to get some inkling of the real nature of electricity. Roughly speaking, it may be stated that a dynamo produces current because its magnets set up strains in the ether and the conductors on the armature have the power of absorbing these strains and of thus producing so-called electric currents; it is only, however, by the expenditure of mechanical energy in moving the conductors of the armature that these strains in the ether can be absorbed, so that a dynamo may be considered merely as a machine for converting mechanical into electrical energy.

INTERNAL WIRING OF BUILDINGS

During the last few decades the science of electricity has advanced in a remarkable manner, and an international system of units of measurements has been developed based on what is known as the French C.G.S. system — that is, the centimeter; gramme and second system. This system will now be shortly described.

The centimeter is the equivalent to ·3937 of an inch, and is approximately the length of a quadrant of the earth divided by 1,000,000,000.

A gramme is the mass of a cubic centimeter of water at 4° cent. One thousand grammes (called a kilogramme) is about 2·2 pounds in weight.

The second is the same as the English second. The fundamental unit of force, called the dyne, is defined as that capable of imparting a motion of one centimeter per second to a mass of one gramme. The force of gravity compels bodies in vacuo to fall 32·2 feet in the first second from rest; it therefore exercises in C.G.S. units a force of

$$\frac{32{\cdot}2 \times 12}{{\cdot}3937} = 981 \text{ dynes.}$$

Similarly the fundamental unit of work, called the erg, is the amount of work done in moving a body through a length of one centimeter against a force of one dyne.

A unit magnet pole is such that if placed at a distance of one centimeter from another similar pole it will repel it with a force of one dyne; a unit magnetic pole is thus said to produce one "line of force."

Now, since electromotive force is produced by a

conductor cutting lines of force, the fundamental unit of electromotive force is that produced by a conductor cutting one line of force per second.

The fundamental unit of current is such that if one centimeter length of the conductor conveying it is bent into an arc having a radius of one centimeter, it will act on a unit magnetic pole placed at radius distance with a force of one dyne.

The fundamental unit of resistance is that of a conductor of such dimensions that with unit electromotive force at its ends it allows unit current to pass through its substance.

The fundamental units of electromotive force and resistance as given above are far too small to be of any practical value; therefore the practical unit of electromotive force, called the " volt," is the fundamental unit multiplied by 10^8, and the practical unit of resistance, called the " Ohm," is the fundamental unit multiplied by 10^9.

The practical unit of current on the other hand is 1/10 of the fundamental unit, and is called the " ampère."

The " Watt " is the unit rate at which electrical energy is produced, and is the product of the pressure and the quantity of the current.

The well-known Ohm's law states that the current in a conductor is directly proportional to the electromotive force (or volts) producing that current, and inversely proportional to the resistance of the conductor. Thus, calling the electromotive force or volts E, the current C, and the resistance R,

Ohm's law states that $\frac{E}{R} = C$; whence $CR = E$, and also $EC = C^2R$.

On these simple formulæ are based nearly all the calculations used in "wiring"; and if once thoroughly grasped, the calculations become quite simple.

A *kilowatt* is one thousand watts, and one kilowatt produced for one hour is known as a Board of Trade unit among central station engineers.

A *megohm* is one million ohms.

The above terms will be frequently employed, and should more exact information be required about them, any elementary text-book on electricity will furnish it; but in order to give the reader some general ideas of their values, it may be of interest to mention that the rate of working known as a horse-power, and estimated by Watt as being equivalent to a weight of 33,000 pounds being raised at the rate of one foot in a minute, is represented electrically by 746 watts, or very nearly three-quarters of a kilowatt. Again, an ordinary 16 candle-power incandescent lamp absorbs electric energy at the rate of 60 watts; hence, as 1,000 watts for an hour constitutes a "unit," it follows that $\frac{1000}{60} = 16$ lamps, each of 16 candle-power, burning for an hour, absorb electric energy to the extent of about one unit. Consumers of current from central stations are generally charged by the unit, and the above example will give a rough idea of the amount of light for one hour that can be obtained per unit. It is here assumed that a 16 candle-power lamp

absorbs 60 watts, and such is generally the case. Lamps can, however, be manufactured of the same candle-power to absorb only 40 watts, but they are not so durable as 60-watt lamps.

The usual voltages at which current is supplied from central stations are 100 or 200 volts ; assuming a pressure of 100 volts, the resistance of a 60-watt lamp of 16 candle-power can be found by a simple application of Ohm's law thus : $\frac{EC}{E}=C$; but $EC=60$

and $E=100$,

therefore the current $=\frac{60}{100}=\cdot 6$ ampère ;

and since $\frac{E}{R}=C$, and $C=\cdot 6$,

therefore $R=\frac{100}{\cdot 6}=133$ ohms.

Numerous simple calculations of this description occur in work connected with wiring, and will be dealt with as occasion arises.

As certain pieces of apparatus are always used in every electrical installation, it may be as well to explain here that a *switch* is an appliance for making or breaking an electric circuit, and consists of a pivoted piece of metal that can be turned in such a manner that it either makes a metallic connection between two conductors or severs it.

Cut-outs, or *fuses*, are appliances for inserting pieces of an easily-fusible metal into the electric circuit, so that in case of a sudden large increase of current this metal melts and so cuts off the current automatically.

When alternating currents are employed, strictly speaking the calculations derived from Ohm's law should be modified;[1] but in ordinary wiring work, where the capacity of the conductors does not play an important part, and the currents and cables employed are not of an exceptionally heavy nature, the calculations may be carried out on the same lines as those for direct currents.

[1] See Appendix.

CHAPTER II

Electric Cables

OF all the materials used in wiring, the most important, from every point of view, are the cables or insulated conductors. These have to be insulated to avoid any possibility of positive or negative wires coming in contact with one another, either directly, owing to the resistance of the lamps being omitted, or indirectly, by moisture or any semi-conducting substance, such as wet plaster or cement. The consequences that may ensue should the positive and negative wires from any cause become directly connected, and thus cut out the resistance of the lamps, may be of a very disastrous nature, and what is known as a "short circuit" at once takes place. This is of the same nature as an explosion, an immense amount of electrical energy being suddenly liberated, which heats the conductors to such an extent that either some portion of the metallic circuit is melted or else damage is done to the machinery producing the current. It is always possible for short circuits to occur; it is necessary, therefore, to distribute what are known as "fuses" or "cut-outs" at different points in the

circuits, so that in the event of a short circuit the fuse, which is made of easily fusible metal, at once melts, owing to the excess of current, and automatically cuts off the current before the copper conductors are sensibly heated.

If moisture finds its way through the insulated coverings to the metallic cores of the conductors, an "earth" connection is thus set up, with the result that the current leaks away from one pole through the moisture or "earth" to the other pole. Electrolytic action then takes place, which dissolves the copper on the positive conductor to such an extent that the circuit is eventually broken. If the moisture is a good conductor a "dead earth" connection is set up, and is likely to be as disastrous as a short circuit. In fact, earth connections generally are a source of such great danger that companies supplying the current from central stations invariably refuse to connect a building to their mains, if any decided earth connection can be detected by means of the testing instruments usually employed.

It will thus be seen that the insulation of cables is of great importance, and when it is remembered that the insulating material must be pliable to allow the cables to be bent, and at the same time of a quality capable of resisting changes of temperature without deterioration, it will be readily understood that india-rubber is one of the best materials that can be employed, as in addition to its other qualities it is a very good non-conductor of electricity. Many other substances are used, such as bitumen, resin, and paper treated with

paraffin; but in the large majority of cases india-rubber is the insulating material employed, and in order to give it more lasting qualities it is generally vulcanized. Without entering into the details of cable manufacturing it must suffice to say that the insulation of a good serviceable conductor for general wiring work will consist of layers of insulated pure and vulcanizing rubber and proofed tape, all thoroughly vulcanized together, then braided and served with a special compound. The diameter of wires forming the conductors of cables is measured by certain gauges which have been in use for periods long before electric lighting came into general vogue. These gauges are known as the Birmingham, Brown and Sharpe, and Standard wire gauges. There are very slight differences between the three, as will be seen by reference to the tables.

For the sake of flexibility and to minimize the chances of breaking a conductor, it is best to use several strands of copper. In practice the smallest size of stranded conductor consists usually of three strands of No. 22 S.W.G.; larger sizes of cables consist of 7, 19, 37, and even 61 and 91 strands for very large sizes. These numbers are chosen because it is found that they give a circular form to the cross section. It is often advisable to use a cable of many strands in preference to one with a smaller number in order to gain the advantage of greater flexibility. Thus, a 19/18 cable is easier to fix where a large number of corners have to be turned than a 7/14 cable, which is of about the same size but much stiffer to handle.

Sizes of Cables to be Employed.—There are two principal considerations that determine the sizes of conductors to be employed in any building. The first is the amount of heat produced by the current and the resistance of the conductors, and the second is the drop in electrical pressure due to the resistance of the conductor. The conditions in these two respects are to a limited extent analogous to the conditions under which water flows in pipes. Loss of pressure occurs in pipes owing to the friction or resistance to flow, and the cross section has to be proportioned to the quantity of water flowing. Similarly, when an electric current passes along a conductor the latter offers a resistance to its passage in strict proportion to its size or cross sectional area, and if the current is very large and the sectional area small, the loss in electrical pressure may be considerable and cause a very sensible heating of the conductor. If carried to extremes the heating may result in the melting of the conductor. In an incandescent lamp the filament becomes white hot because the resistance is very great and the current large in proportion to the sectional area of the filament.

Table showing the Differences between the various Wire Gauges in Use.

Standard Wire Gauge Diameter.			Birmingham Wire Gauge Diameter.			Brown and Sharpe Wire Gauge Diameter.		
No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.
0	·324	8·229	0	·340	8·635	0	·3249	8·252
1	·300	7·620	1	·300	7·620	1	·2893	7·348
2	·276	7·010	2	·284	7·213	2	·2576	6·543
3	·252	6·400	3	·259	6·578	3	·2294	5·827
4	·232	5·893	4	·238	6·045	4	·2043	5·189
5	·212	5·385	5	·220	5·588	5	·1819	4·620
6	·192	4·877	6	·203	5·156	6	·1620	4·115
7	·176	4·470	7	·180	4·5719	7	·1443	3·665
8	·160	4·064	8	·165	4·1909	8	·1285	3·264
9	·144	3·658	9	·148	3·7591	9	·1144	2·906
10	·128	3·251	10	·134	3·4035	10	·1019	2·588
11	·116	2·946	11	·120	3·0479	11	·0907	2·304
12	·104	2·642	12	·109	2·7701	12	·0808	2·052
13	·092	2·337	13	·095	2·4129	13	·0720	1·829
14	·080	2·032	14	·083	2·1082	14	·0641	1·628
15	·072	1·829	15	·072	1·8288	15	·0571	1·450
16	·064	1·626	16	·065	1·6510	16	·0508	1·290
17	·056	1·422	17	·058	1·4732	17	·0452	1·150
18	·048	1·219	18	·049	1·2446	18	·0403	1·024
19	·040	1·016	19	·042	1·0668	19	·0354	·900

Standard Wire Gauge Diameter.			Birmingham Wire Gauge Diameter.			Brown and Sharpe Wire Gauge Diameter.		
No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.
20	·036	·914	20	·035	·8890	20	·0320	·813
21	·032	·813	21	·032	·8128	21	·0285	·724
22	·028	·711	22	·028	·7112	22	·0253	·643
23	·024	·610	23	·025	·6350	23	·0226	·574
24	·022	·559	24	·022	·5588	24	·0201	·511
25	·020	·508	25	·020	·5080	25	·0179	·455
26	·018	·457	26	·018	·4571	26	·0159	·404
27	·0164	·417	27	·016	·4064	27	·0142	·361
28	·0148	·376	28	·014	·3556	28	·0126	·320
29	·0136	·345	29	·013	·3302	29	·0112	·284
30	·0124	·315	30	·012	·3048	30	·0100	·254
31	·0116	·295	31	·0115	·2920	31	·0089	·2261
32	·0108	·274	32	·0110	·2793	32	·0079	·2007
33	·0100	·254	33	·0100	·2539	33	·0071	·1803
34	·0092	·2337	34	·0095	·2412	34	·0063	·1600
35	·0084	·2134	35	·0087	·2209	35	·0056	·1422
36	·0076	·1930	36	·0079	·2006	36	·0050	·1270
37	·0068	·1727	37	·0073	·1854	37	·0044	·1117
38	·0060	·1524	38	·0068	·1727	38	·0039	·0990
39	·0052	·1321	39	·0063	·1600	39	·0035	·0888
40	·0048	·1219	40	·0058	·1473	40	·0031	·0787

Details of Conductors. Showing

Size. S.W.G	Ampères at 1,000 per square inch at above ratio, Loss= approx. 2½ volts per 100 yards.	Ampères at I. E. E. Standard.	Diameter. Inches.	Diameter. Millimetres.	Area. Square Inches.	Area. Square Millimetres.
22	0·6158	1·7	.028	0·7112	·0006158	·3973
21	·8042	2·2	·032	0·8128	·0008042	·5188
20	1·0179	2·6	·036	0·9144	·001018	·6567
19	1·2566	3·2	·040	1·016	·001257	·8109
18	1·8096	4·2	·048	1·219	·001810	1·168
17	2·4630	5·4	·056	1·422	·002463	1·589
16	3·2170	6·8	·064	1·626	·003217	2·075
15	4·0715	8·2	·072	1·829	·004072	2·627
14	5·0265	9·8	·080	2·032	·005027	3·243
13	6·6476	12·4	·092	2·337	·006648	4·289
12	8·4949	15·0	·104	2·642	·008495	5·480
11	10·568	18·0	·116	2·946	·01057	6·819
10	12·868	21·0	·128	3·251	·01287	8·303
9	16·286	27·0	·144	3·658	·01629	10·51
8	20·106	31·0	·160	4·064	·02011	12·97
7	24·328	36·0	·176	4·470	·02433	15·70
6	28·952	42·0	·192	4·877	·02895	18·68
5	35·298	48·0	·212	5·385	·03530	22·77
4	42·273	57·0	·232	5·893	·04227	27·27
3	49·875	64·0	·252	6·401	·04988	32·18
2	59·828	75·0	·276	7·010	·05083	38·60
1	70·685	85·0	·300	7·620	·07069	45·60
1/0	82·447	97·0	·324	8·230	·08245	53·19
2/0	95·114	108·0	·348	8·839	·09511	61·36
3/0	108·68	120·0	·372	9·449	·1087	70·13
4/0	125·66	135·0	·400	10·16	·1257	81·09
5/0	146·57	155·0	·432	10·97	·1466	94·58
6/0	169·09	173·0	·464	11·79	·1691	109·1
7/0	196·34	196·0	·500	12·70	·1963	126·6

Dimensions, Capacity, Resistance and Weight.

Standard Resistance at 60° Fahr.			Standard Weight.		Size.
Ohms per 1,000 Yards.	Ohms per Mile.	Ohms per Kilo-metre.	Pounds per 1,000 Yards.	Pounds per Mile.	S.W.G.
39·05	68·72	42·70	7·120	12·53	22
29·90	52·62	32·70	9·301	16·37	21
23·62	41·57	25·83	11·77	20·72	20
19·13	33·67	20·92	14·53	25·58	19
13·28	23·38	14·53	20·93	36·83	18
9·762	17·18	10·68	28·48	50·12	17
7·478	13·16	8·178	37·20	65·47	16
5·904	10·39	6·456	47·09	82·87	15
4·784	8·419	5·232	58·13	102·3	14
3·617	6·366	3·956	76·88	135·3	13
2·831	4·982	3·096	98·24	172·9	12
2·275	4·004	2·488	122·2	215·1	11
1·868	3·228	2·043	148·8	261·9	10
1·476	2·598	1·614	188·4	331·5	9
1·195	2·104	1·307	232·5	409·2	8
·9881	1·739	1·081	281·3	495·1	7
·8307	1·462	·9085	334·7	589·1	6
·6813	1·199	·7451	408·2	718·4	5
·5688	1·001	·6220	488·8	860·2	4
·4821	·8484	·5272	576·7	1015·0	3
·4019	·7073	·4395	692·0	1218·0	2
·3402	·5987	·3720	817·6	1439·0	1
·2917	·5133	·3190	953·4	1678·0	1/0
·2528	·4450	·2765	1099·0	1935·0	2/0
·2212	·3893	·2419	1257·0	2212·0	3/0
·1913	·3367	·2092	1453·0	2558·0	4/0
·1640	·2887	·1794	1695·0	2983·0	5/0
·1422	·2503	·1555	1955·0	3441·0	6/0
·1225	·2156	·1340	2270·0	3995·0	7/0

DETAILS OF CONDUCTORS (*continued*).

Size. S.W.G.	Ampères at 1,000 per square inch.	Ampères at I. E. E. Standard.	Diameter of each Wire. In Inches.	Diameter of each Wire. In Millimetres.	Diameter of Strand. In inches.	Diameter of Strand. In Millimetres.
3/25	·9311	2·452	·020	·5080	·043	1·092
3/24	1·127	2·868	·022	·5588	·047	1·194
3/23	1·341	3·307	·024	·6096	·052	1·321
3/22	1·825	4·258	·028	·7112	·060	1·524
3/21	2·384	5·301	·032	·8128	·069	1·753
3/20	3·016	6·444	·036	·9144	·078	1·981
3/19	3·725	7·644	·040	·1016	·086	2·184
3/18	5·364	10·31	·048	·1219	·103	2·616
7/25	2·177	4·921	·020	·5080	·060	1·524
7/24	2·633	5·751	·022	·5588	·066	1·676
7/23	3·135	6·636	·024	·6096	·072	1·829
7/22	4·266	8·543	·028	·7112	·084	2·134
7/21½	4·896	9·565	·030	·7620	·090	2·286
7/21	5·571	10·63	·032	·8128	·096	2·438
7/20½	5·925	11·19	·033	·8382	·099	2·515
7/20	7·052	12·90	·036	·9144	·108	2·743
7/19	8·708	15·34	·040	1·016	·120	3·048
7/18	12·54	20·68	·048	1·219	·144	3·658
7/17	17·06	26·62	·056	1·422	·168	4·267
7/16	22·27	33·12	·064	1·626	·192	4·877
7/15	28·22	40·22	·072	1·829	·216	5·486
7/14	34·83	47·80	·080	2·032	·240	6·096
7/13	46·05	60·10	·092	2·337	·276	7·010
7/12	58·84	73·47	·104	2·642	·312	7·925
7/11	73·22	87·90	·116	2·946	·348	8·839
7/10	89·17	103·3	·128	3·251	·384	9·754
7/9	112·9	125·4	·144	3·658	·432	10·97
7/8	139·3	149·0	·160	4·064	·480	12·19
7/6	200·6	200·9	·192	4·877	·576	14 63

Effective Area, viz. Area of Solid Wire having some Conductivity.		Standard Resistance at 60° Fahr.			Standard Weight per Mile.	Size.
Square Inches.	Square Milli-metres.	Per 1,000 yards.	Per mile.	Per Kilo-metre.		S.W.G.
·0009311	·6007	25·82	45·45	28·24	19·42	3/25
·001127	·7271	21·33	37·55	23·33	23·49	3/24
·001341	·8651	17·94	31·57	19·62	27·96	3/23
·001825	1·177	13·18	23·19	14·41	38·05	3/22
·002384	1·538	10·09	17·75	11·03	49·71	3/21
·003016	1·946	7·972	14·03	8·718	62·92	3/20
·003725	2·403	6·455	11·36	7·059	77·68	3/19
·005364	3·461	4·482	7·889	4·902	111·8	3/18
·002177	1·404	11·05	19·44	12·08	45·23	7/25
·002633	1·699	9·131	16·07	9·986	54·71	7/24
·003135	2·023	7·670	13·50	8·389	65·12	7/23
·004266	2·752	5·636	9·920	6·164	88·63	7/22
·004896	3·159	4·910	8·643	5·371	101·8	7/21½
·005571	3·594	4·316	7·596	4·720	115·8	7/21
·005925	3·822	4·059	7·143	4·439	123·2	7/20½
·007052	4·550	3·410	6·001	3·729	146·6	7/20
·008708	5·618	2·761	4·860	3·020	180·9	7/19
·01254	8·090	1·918	3·375	2·097	260·5	7/18
·01706	11·01	1·410	2·480	1·541	354·5	7/17
·02227	14·37	1·080	1·900	1·181	463·1	7/16
·02822	18·21	·8523	1·500	·9321	586·2	7/15
·03483	22·47	·6903	1·215	·7550	723·6	7/14
·04605	29·71	·5222	·9190	·5711	957·1	7/13
·05884	37·96	·4086	·7192	·4469	1223·0	7/12
·07322	47·24	·3284	·5780	·3592	1522·0	7/11
·08917	57·53	·2697	·4746	·2950	1853·0	7/10
·1129	72·84	·2131	·3750	·2330	2345·0	7/9
·1393	89·97	·1726	·3037	·1887	2894·0	7/8
·2006	129·4	·1199	·2110	·1311	4167·0	7/6

Details of Conductors (*continued*).

Size. S. W. G.	Ampères at 1,000 per Square Inch.	Ampères at I. E. E. Standard.	Diameter of each Wire. In Inches.	Diameter of each Wire. In Millimetres	Diameter of Strand. In Inches.	Diameter of Strand. In Millimetres.
19/22	11·57	19·36	·028	·7112	·140	3·556
19/21	15·10	24·09	·032	·8128	·160	4·064
19/20	19·12	29·23	·036	·9144	·180	4·572
19/19	23·60	34·74	·040	1·016	·200	5·080
19/18	33·99	46·85	·048	1·219	·240	6·096
19/17	46·27	60·33	·056	1·422	·280	7·112
19/16	60·39	75·06	·064	1·626	·320	8·128
19/15	76·50	91·12	·072	1·829	·360	9·144
19/14	94·42	108·3	·080	2·032	·400	10·16
19/13	124·9	136·2	·092	2·337	·460	11·68
19/12	159·5	166·4	·104	2·642	·520	13·21
19/11	198·5	199·2	·116	2·946	·580	14·73
19/10	241·7	234·0	·128	3·251	·640	16·26
37/20	37·22	50·47	·036	·9144	·252	6·401
37/19	45·96	61·07	·040	1·016	·280	7·112
37/18	66·19	80·91	·048	1·219	·336	8·534
37/17	90·06	104·2	·056	1·422	·392	9·957
37/16	117·6	129·6	·064	1·626	·448	11·38
37/15	148·9	157·3	·072	1·829	·504	12·80
37/14	183·8	187·0	·080	2·032	·560	14·22
37/13	243·1	235·2	·092	2·337	·644	16·36
37/12	310·5	287·4	·104	2·642	·728	18·49
61/18	109·1	121·9	·048	1·219	·432	10·97
61/17	148·5	157·0	·056	1·422	·504	12·80
61/16	193·9	195·4	·064	1·626	·576	14·63

Effective Area, viz. Area of Solid Wire having same Conductivity.		Standard Resistance at 60° Fahr.			Standard Weight per Mile.	Size.
Square Inches.	Square Millimetres.	Per 1,000 Yards.	Per Mile.	Per Kilometre.		S. W. G.
·01157	7·464	2·079	3·659	2·274	240·8	19/22
·01510	9·742	1·592	2·802	1·741	314·6	19/21
·01912	12·34	1·257	2·213	1·375	398·3	19/20
·02360	15·23	1·019	1·793	1·114	491·7	19/19
·03399	21·93	·7074	1·245	·7736	707·9	19/18
·04627	29·85	·5197	·9147	·5684	963·3	19/17
·06039	38·96	·3981	·7007	·4354	1258·0	19/16
·07650	49·35	·3143	·5532	·3437	1593·0	19/15
·09442	60·91	·2547	·4482	·2785	1966·0	19/14
·1249	80·58	·1926	·3389	·2106	2601·0	19/13
·1595	102·9	·1507	·2653	·1649	3323·0	19/12
·1985	128·1	·1211	·2132	·1325	4134·0	19/11
·2417	155·9	·09949	·1751	·1088	5034·0	19/10
·03722	24·01	·6460	1·137	·7065	775·8	37/20
·04596	29·65	·5232	·9208	·5722	957·9	37/19
·06619	42·70	·3633	·6394	·3973	1379·0	37/18
·09006	58·10	·2670	·4699	·2920	1877·0	37/17
·1176	75·87	·2045	·3599	·2236	2451·0	37/16
·1489	96·06	·1615	·2842	·1766	3103·0	37/15
·1838	118·6	·1309	·2303	·1431	3830·0	37/14
·2431	156·8	·09892	·1741	·1082	5066·0	37/13
·3105	200·3	·07744	·1363	·08469	6474·0	37/12
·1091	70·38	·2204	·3879	·2410	2274·0	61/18
·1485	95·80	·1619	·2850	·1770	3094·0	61/17
·1939	125·1	·1240	·2183	·1356	4042·0	61/16

Details of Conductors (*continued*).

Size. S. W. G.	Ampères at 1,000 per Square Inch.	Ampères at I. E. E. Standard.	Diameter of each Wire. In Inches.	Diameter of each Wire. In Millimetres.	Diameter of Strand. In Inches.	Diameter of Strand. In Millimetres.
61/15	245·5	237·0	·072	1·829	·648	16·46
61/14	302·9	281·6	·080	2·032	·720	18·29
61/13	400·8	354·3	·092	2·337	·828	21·03
61/12	512·0	433·1	·104	2·642	·936	23·77
91/14	451·9	391·0	·080	2·032	·880	22·35
91/13	597·7	491·7	·092	2·337	1·012	25·70
91/12	763·8	600·1	·104	2·642	1·144	29·06
91/11	950·4	719·3	·116	2·946	1·276	32·41

In order to calculate the energy lost in heating, due to the passage of the current along conductors, it becomes necessary to know the resistance in ohms of given lengths of the cables employed. Now the "specific resistance" of copper, *i.e.* the resistance of a piece of given dimensions compared with the resistance of a piece of silver of similar dimensions, has been ascertained with great accuracy, and taking the resistance of silver as unity, the relative resistance of annealed copper is 1·063 at 0° Centigrade. If, therefore, the actual resistance in ohms of a given length of silver wire, say one yard long and $\frac{1''}{100}$ diameter, is known, the resistance

Effective Area, viz. Area of Solid Wire having same Conductivity.		Standard Resistance at 60° Fahr.			Standard Weight per Mile.	Size.
Square Inches.	Square Mil i-metres.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.		S. W. G
·2455	158·4	·09795	·1724	·1071	5116·0	61/15
·3029	195·4	·07937	·1397	·08681	6316·0	61/14
·4008	258·6	·06000	·1056	·06562	8353·0	61/13
·5120	330·3	·04697	·08266	·05136	10674·0	61/12
·4519	291·5	·05320	·09364	·05819	9442·0	91/14
·5977	385·6	·04023	·07080	·04400	12462·0	91/13
·7638	492·8	·03148	·05541	·03443	15925·0	91/12
·9504	613·1	·02530	·04453	·02767	19811·0	91/11

of a similar piece of copper wire can be calculated, and from this again any lengths of copper conductors, always bearing in mind that the resistance is proportional to the length and inversely proportional to the cross sectional area. Complete tables are here given of the more usual sizes of conductors used in wiring, giving the resistances, sizes, weights and diameters, including insulation, and the current giving 2½ volts drop in pressure for every 100 yards of double run.

Suppose, for instance, it is required to know the resistance of 100 yards of 3/22 cable, a size very frequently used in wiring work. From books we find that the resistance of the above-mentioned yard of

silver wire of $\frac{1''}{100}$ diameter is ·2714 ohm. Therefore the resistance of a similar piece of annealed copper wire is $\cdot 2714 \times 1{\cdot}063 = \cdot 2885$ ohm. The sectional area of wire $\frac{1''}{100}$ diameter is ·0000785□″, and of a single wire of 22 gauge (of which the diameter is ·028″) is ·0006154□″. A 3/22 stranded wire has therefore a sectional area of $\cdot 000615'' \times 3 = \cdot 001846$□″. The resistance then of 1 yard is $\cdot 2885 \times \frac{\cdot 0000785}{\cdot 001846} = \cdot 01226$ ohm. Therefore the resistance of 100 yards of 3/22 is 1·226 ohms. This number is not quite the same as that given in the table, the explanation being that the sectional area is slightly larger than ·001846 owing to the fact that the three strands of wire are put together in a slightly spiral form, consequently the sectional area is greater than if all the wires were perfectly straight. In the tables, account is taken of the decrease of resistance due to the spiral winding of the stranded conductors.

Current Density in Conductors.—The greater the current that passes through a conductor of given diameter the greater is the loss in pressure and the heat produced; hence it is necessary to fix some proportion between the diameters of conductors and the current they shall carry, in order to avoid overheating. For the internal wiring of buildings any danger of overheating can be avoided by using conductors of such a sectional area that the current in them shall not be proportionately greater than

1,000 ampères per square inch of sectional area of conductor, or, in other words, the "current density" must not exceed 1,000 ampères per square inch. Thus the maximum current that should be carried by a 3/22 cable of which the sectional area is ·0018″ is 1,000 × ·0018 or 1·8 ampères. It will be seen from this that it is only necessary to multiply the area of a conductor (in square inches) by 1,000 to find the maximum carrying capacity in ampères. In order to avoid undue loss of pressure, it is very frequently advisable to employ larger conductors than those given by this rule, but as regards heating effects only, the 1,000 ampères per square inch rule is very largely adopted as a practical rule of thumb guide for determining the sizes of conductors. This rule is empirical and can be relied on to this extent only, that it will not under any circumstances permit pure copper conductors to become dangerously hot, but it is no guide at all as to the ultimate temperature the conductor will reach; this depends on a variety of circumstances into which it is not necessary to enter here.[1] In the tables of details of conductors, the resistances, weights, areas, loss in pressure per 100 yards run are given, so that any calculation requiring these figures can be easily made.

Where the conductors are not of pure copper, as in switchboards, wall sockets, ceiling roses, etc., it is necessary to allow a much lower current density, as the brass or gun-metal of which these are made has a higher specific resistance than pure copper; conse-

[1] See Appendix

quently the heating effect with a given current is greater, and the current density should not be allowed under any circumstances to exceed 500 ampères per square inch.

If the current density is kept within the 1,000 ampères per square inch limit, it will be found that in most buildings not only is there no danger from overheating, but also that the drop in pressure at the ends of the circuits is not excessive, being generally not more than 2 or 3 per cent. of the total voltage. In specifications issued by consulting engineers it is often stipulated that this drop shall not exceed 2 per cent. at the ends of the longest circuits. In buildings, therefore, where the runs are likely to be long, it becomes necessary to calculate carefully the sizes of the conductors, to see if the 1,000 ampère per square inch rule allows sufficient area of conductor.

Now the electrical pressure or "voltage" employed determines largely the size of conductors to be employed; thus it has been mentioned above that an incandescent lamp of 16 candle-power requires 60 watts to bring it to a normal incandescence. This energy may be delivered theoretically at any voltage, provided the lamp is suitably made. If, for instance, a pressure of 10 volts were employed, the current would be $\frac{60}{10} = 6$ ampères; but if it should be 200 volts, the current becomes $\frac{60}{200} = \cdot 3$ ampère, or

$\frac{1}{20}$ of the former amount. It is obvious, therefore, that a conductor to carry 6 ampères must be 20 times larger than one used to carry ·3 ampère, provided the current density in each is the same. Similar conditions would obtain in two water pipes delivering the same energy in water, but at pressures differing as 1 : 20. The pipe carrying the water at the lower pressure would require a sectional area 20 times larger than that of the other. By increasing the voltage of lamps, therefore, the current can be correspondingly decreased and a large saving effected in the copper employed in the conductors. This is of great practical importance, and there is a general tendency to increase the voltage of lamps. At the present time the limit is about 250 volts, and it is not improbable that even this high voltage may be increased. It must be remembered, however, that with the higher pressures employed the difficulties of efficiently insulating the conductors increase, and special apparatus has to be introduced in order to ensure safety to the consumers of electrical energy. It may be mentioned here that wires for electric bell connections are very lightly insulated simply because the pressure is very small (not exceeding one or two volts), consequently there is little danger of the insulation breaking down.

By raising the voltage then the current is decreased, and this decrease means also a smaller loss of pressure over a given resistance. There is therefore a double gain, decrease of loss of pressure and

diminution of current. This follows directly from Ohm's law, which states that $E = CR$ or $EC = C^2R$.

From this it will be seen that any diminution of current in a given conductor causes the power (EC) lost to vary inversely as the square of the current. The power thus lost is frequently referred to as the C^2R or frictional losses.

In order to gain the full advantages of higher pressure, supply companies for direct current are making great efforts to induce their customers to adopt higher voltage lamps ; and in cases where this has been done, it has been possible to extend the lighting areas from given centres to a very large extent.

An example may make this more clear. Suppose 100 16-c.p. lamps of 60 watts each and 100 volts are fixed at the end of a 19/16 cable 100 yards long altogether. The resistance of this length is ·0406 ohm, and the current taken by the lamps is $100 \times \cdot 6 = 60$ ampères. The loss in pressure along this cable will be $60 \times \cdot 0406 = 2 \cdot 439$ volts, and the loss in watts $60 \times 2 \cdot 439 = 146 \cdot 37$ watts. If now the voltage of the lamps is increased to 200 volts the current is halved to 30 ampères. The resistance of the cable remains the same, and the loss in pressure becomes $30 \times \cdot 0406 = 1 \cdot 219$, and the loss in watts $30 \times 1 \cdot 219 = 36 \cdot 59$. This is ¼ the watts lost in the former case. In order to obtain the same loss in watts in the same length, the cable at the higher voltage would be ¼ the size, or, to put it in another way, the same loss in watts would occur if the cable were four times as long. In the wiring

of buildings a considerable economy can be effected in the size of conductors by increasing the pressure, and in cases where the wiring has already been put in to carry current for lamps of 100 volts, if the voltage is changed to 200, no less than 4 times the number of lamps can theoretically be used with the same loss in watts. In practice, however, it is not advisable to allow more than double the number of lamps, for the current density is only halved, and if the conductors were originally put in allowing 1,000 ampères per square inch, it is not usual to allow a greater current density than this.

CHAPTER III

General Arrangement of Conductors and Cut-outs in Buildings

AS a general rule the supply of current from a central station or other source is taken into a building in the lower floor, a convenient position being selected for the termination of the mains. At this point a fusible cut-out is placed on each conductor or "pole," and the conductors are then run to the various points throughout the building, and can be gradually diminished in size as they get nearer the top of the building, as the number of lights they have to supply is diminished. It is of the first importance to remember that wherever the size of conductor is diminished a double-pole cut-out *must* be placed where this change of area takes place ; or, in other words, the cut-outs *must be placed at the roots of the branches* from the mains. The function of these cut-outs is not to prevent the lamp filaments from giving way, owing to excess of pressure, but to protect the conductors from dangerous overheating, due either to short circuits or excessive leakage of current.

In towns and situations where the current is obtained from a central station, the work of bringing the mains into the building from the street is undertaken usually by the company supplying the current, and in most cases these short lengths are run in iron barrel, which is by far the most efficient protection for work of this description.

After leaving the company's double-pole fuse, the conductors are run first to a meter, and then to a main double-pole switch and fuse, which must be placed as close as possible to the company's fuses, care being taken that no current whatever is taken from the mains between this switch and company's fuse, otherwise the main switch will not control every light in the building; and, in addition, should any fault be developed behind the main switch, there is no means of cutting off the current, as the fuses of the supply company are generally very large, and not likely to melt except in extreme cases.

After leaving the main double-pole switch and cut-out, the conductors should be taken to various distributing fuse-boards, placed in convenient positions throughout the building, and smaller conductors are run from these boards again to the various points where the lights are required. Distributing boards consist of groups of fuses on each pole fixed to an insulated base, and enclosed usually in boxes to protect them. Later on a fuller description of various fuses will be given.

There are two simple methods of arranging the mains in a building: either one pair of mains can be run, and the various sub-distributing fuse-boards

fed from these by short branches of the same size as the mains, or else the mains themselves can be subdivided at a point where a fuse-box is placed, and from this again smaller mains are run to the smaller distributing boxes. The first plan is suitable for small buildings, as it is very simple, and the second plan for larger buildings, as it admits of each section of the mains being tested separately when necessary. This is of great importance, as it is often difficult to localize faults unless the circuits can be divided into sections. These two systems are diagrammatically shown in Figs. 1 and 2.

Three-wire System.—In large buildings, in which the number of lights is likely to exceed 100, it is a very usual practice to introduce what is known as the "three-wire system." The object of this system is to gain the advantages of higher voltage without increasing the actual voltage of the lamps. The method employed is simple, being merely the connection of two circuits, each supplying current at a given voltage into one system, whereby the pressure is doubled. Thus, *A* and *B* are two separate systems, each supplying current at 100 volts to a number of lamps. If now the two systems are joined together, as in *C*, the pressure over the whole installation becomes 200 volts, but the lamp pressure remains as before, or 100 volts, because the middle wire is so connected that there is never more than 100 volts between it and each of the outside conductors. The advantage of this system may not at first be apparent, as the current in the two outer conductors is the same if the two systems are

connected together or separate, but in *C* it will

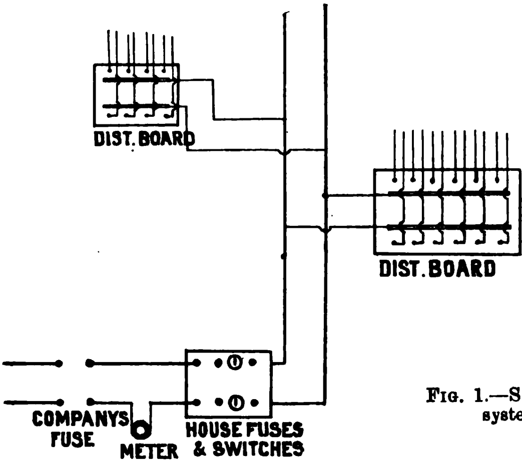


Fig. 1.—Single main system.

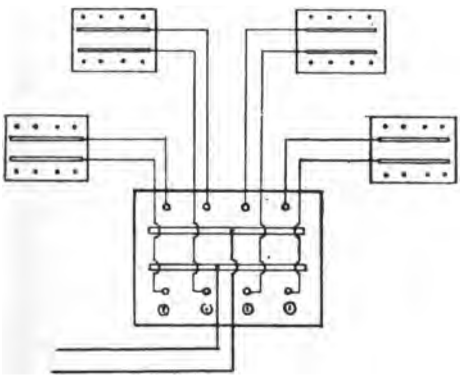
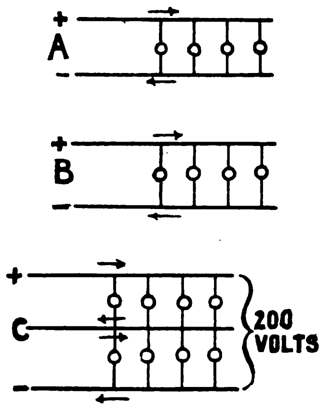


Fig. 2.—Sub-divided main system.

be noted that the current in the middle wire is

marked by the arrows as flowing in opposite directions. This means that the two currents neutralize one another in this portion, and that there is no resultant current in this wire unless the number of lamps on each side of the middle wire is unequal, in which case the balance flows back by it. The gain, therefore, consists in this: that if the current in the two sides of the middle wire is balanced, the



Three-wire system.

current flows through a much shorter length of conductor than it would do otherwise, consequently the loss in pressure is much less. In fact, assuming the current to be taken from the ends of long lengths of conductors, if a three-wire system with the two portions equally loaded is employed instead of two separate systems, the current will travel through half the length of conductors, *i.e.* two wires

instead of four, and the loss of pressure will be halved.

In practice it is seldom if ever possible to so arrange matters that the current is the same on each side of the middle wire, consequently there is generally a current flowing in the middle or balancing wire. As lamps are switched on or off on each side of the middle wire the balance is altered, and if, as is sometimes the case, all the lamps on one side are switched off, the system becomes an ordinary one of two conductors only. This is an extreme case, and care should be taken to arrange the lighting so that the number of lamps alight on each side of the middle wire is about the same. If this is done the middle wire can be made appreciably smaller in area than the outside wires. The exact size to be used can only be approximately determined, and it is usual to allow it to be from about one-third to two-thirds the area of the outer conductor, according to the possibility of obtaining good balancing on each side. Figs. 1 and 2 show two methods of connecting the mains throughout a building to the different fuse-boards on the three-wire system. Fig. 1 shows the simpler method, which may be used for smaller buildings; Fig. 2 the method for larger buildings, where it is necessary to be able to subdivide sections of the mains for testing purposes. In this latter case the full advantage of the three-wire system is only gained up to the main distributing board.

The three-wire system is of great advantage to companies supplying current, inasmuch as it en-

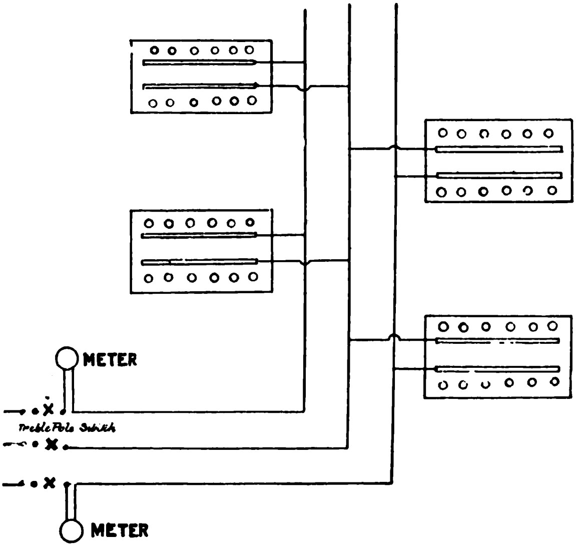


Fig. 1—Three-wire system Simple main.

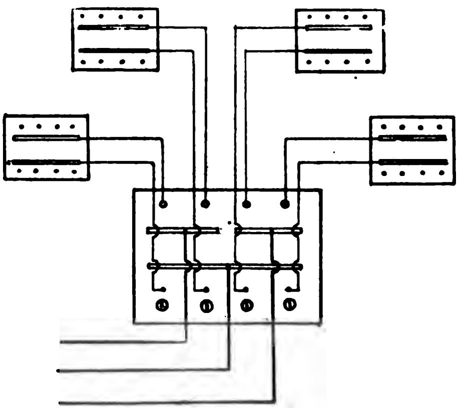


Fig. 2.—Three-wire system. Subdivided mains.

ables them to gain the advantage of the higher voltage. It is not, however, of such corresponding advantage to the consumers, as the various circuits have to be run back to a central distributing board before any advantage can be taken of the system. This is seen in Fig. 2. In buildings where the current amounts to 50 ampères, most supply companies insist that the three-wire system shall be employed.

In order to calculate the loss in pressure in the conductors fixed in a building, we will take as an example an ordinary dwelling-house, in which say 100 lamps of 16 candle-power are fixed and all alight at the same time. We will assume that 100 volts is the pressure, and that each lamp takes 60 watts. Under these circumstances, the current in the mains supplying the whole house will be 60 ampères, distributed as follows :—

3rd floor . .	10 lamps,	or	6	ampères.
2nd ,, . .	15 ,,	,,	9	,,
1st ,, . .	30 ,,	,,	18	,,
Ground floor .	30 ,,	,,	18	,,
Basement .	15 ,,	,,	9	,,
	100 lamps.		60	ampères.

We will assume the current for the lamps on the various floors is taken from 3 distribution boards shown on the 1st and 2nd floors and the basement. Now it may be convenient to take current from any given fuse-board to supply lamps on the floors im-

mediately above or below, therefore the number of ampères given on each floor is no accurate indication from which fuse-board the current is taken.

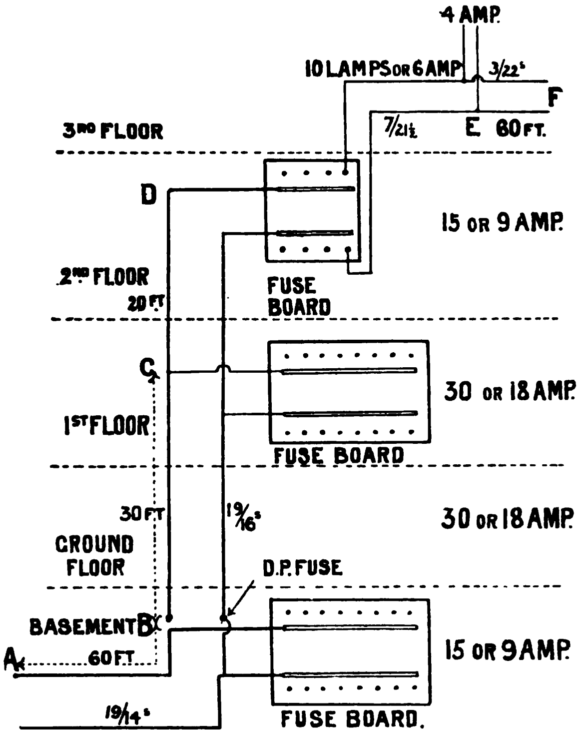


Diagram for calculating loss in mains.

Thus the 30 lamps on the ground floor may be supplied partly from the 1st floor and partly from the basement. We will assume, therefore, that 15

ampères is taken from the 2nd floor board, 30 ampères from the 1st floor board, and 15 ampères from the basement board. At each of the points *B*, *C*, and *D*, 15, 30, and 15 ampères respectively are taken from the mains; therefore the portion *C D* carries 15 ampères, *B C* 45 ampères, while *A B* carries the full 60 ampères. The distances of these various portions are given as 20, 30, and 60 feet respectively; it becomes therefore quite easy to calculate their resistances and the drop of pressure due to the flow of current in them. As that portion of the mains above *B*, however, does not carry the full current, it is assumed that the mains are reduced at this point and a pair of cut-outs fixed.

It will be seen from the tables of cables above given that to carry a current of 60 ampères a 19/14 may be used, assuming a current of under 1,000 ampères per square inch is allowed. Now the resistance of this cable per 100 yards is ·0256 ohm; therefore, if 60 feet run is required, as shown in the figure the resistance will be $\cdot 0256 \times \frac{60 \times 2}{100 \times 3} = \cdot 0102$ ohm, and the loss in pressure $\cdot 0102 \times 60 = \cdot 61$ volt.

Here the length 60 is multiplied by 2 to allow for both positive and negative wires, or "lead" and "return" as they are generally called. From *B* to *C* a smaller conductor can be used to carry 45 ampères, and we will assume this part of the main is taken right up to the fuse-board at *D*. To carry 45 ampères at under 1,000 current density a 19/16 may be used, and the resistance between *B* and *C*, calculated as before, becomes ·008, the resistance per 100

yards of 19/16 being ·04 ohm, and the length 30 feet doubled as before; the loss in pressure is therefore $\cdot 008 \times 45 = \cdot 36$ volt. In the last portion between C and D the resistance becomes ·0046, and the loss in pressure $\cdot 0046 \times 9 = \cdot 041$ volt.

Taking the pressure at A as 100 volts, the pressures at B, C and D by subtraction are found to be respectively, 99·36, 99·03 and 98·9 volts.

We now come to the sub-mains of 5 ampères each, and we will take one as an example, assuming that from the board at D the largest branch of say 60 feet run of 7/21½ takes 6 ampères to E, and that for another 20 feet beyond this a branch of 3/22 takes 1 ampère to the point F.

The resistance of 60 feet run of 7/21½ is seen to be ·2 ohm, and the loss of pressure $\cdot 2 \times 6 = 1 \cdot 2$ volts. Similarly the resistance of the 3/22 is ·17 ohm, and the loss in pressure $\cdot 17 \times 1 = \cdot 17$ volt.

Adding these two losses in pressure together, we get the loss from D 1·37 volts, and the total loss from A $1 \cdot 1 + 1 \cdot 37 = 2 \cdot 47$ volts.

Assuming therefore that the particular sub-branch we have taken is as large as any in the building, the maximum drop in pressure over the whole building has been obtained.

In this particular case it will be seen that the conductors are well within the 1,000 ampère per square inch limit. In large buildings, where the runs are long, in order to avoid a loss of pressure greater than 2 per cent. it may be necessary to put in conductors allowing 800 ampères per square inch.

In a manner similar to the above the drop in

pressure may be calculated in any building, and in the case of a three-wire system it is best to assume all the lamps on one side of the middle wire are switched off, and then calculate the drop as in an ordinary two-wire system as above.

Fusible Cut-outs.—In the arrangement of wiring in a building the correct placing of the fuses is of

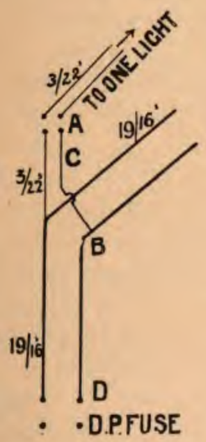


Diagram showing position of fuses.

primary importance. The diagrams already given will indicate to some extent how those fuses should be placed, and it has been stated that wherever the conductors are reduced in area a cut-out should be fixed. This is a regulation always insisted on by fire insurance companies, and should receive careful attention, otherwise sections of the conductors may become dangerously heated and cause considerable damage.

Suppose, for instance, a small conductor, say a 3/22, supplying current for one light, is connected to a much larger main, say 19/16 cable, carrying current for a considerable number of lamps, and the small fuses are placed at *A* instead of *B*. If now a short circuit should occur anywhere between *A* and *B*, say at *C*, there is a sudden rush of current through the small conductors, which heats them to such an extent that they attain a dangerous heat, or else the larger fuses at *E* are melted. In any case some part of the circuit must give way, probably setting fire to the insulation, and the rupture takes place at the weakest point. It is obvious that if the small fuses had been placed at *B* the fusible wire would have melted at once and no undue heating of the conductors have taken place, for fuses are supposed to melt at currents about 50 per cent. in excess of the lamp currents controlled by the fuses.

Fuses and fuse-boards should always be placed in easily accessible positions, and should be so designed that the fuses are quite easy to repair. When electric lighting was first introduced, small branches were taken off the mains at any convenient points, and crude round porcelain fuses fixed indiscriminately under floors or in ceilings as might be most convenient to the wiring contractor. These were always getting out of order, and when broken were liable to set up earth connections, so that it was no uncommon thing to find that even when lamps were switched off the lights did not go out, owing to the earth connections completing the circuits. Now, however, it is the general practice to group

fuses together, and to place them in boxes in convenient positions, so that if a fuse melts it can be easily replaced, and should any fault occur in the wiring, all the small branches can be tested from these centres of distribution. These fuses are on each pole, so that they may act in every case of excess of current due either to short circuiting or leakage to earth on either pole. For incandescent lighting it is a usual practice to run circuits of about 5 ampères or 8 lamps of 16 c.p. at 100 volts from the double pole fuses in the sub-distribution boards, using conductors of 7/21½ gauge, and to put no further double pole fuses, even if the branches are further reduced to 3/22 in size. The fact that these small sub-branches are thus reduced in area without the protection of fuses is no doubt not recognized by the authorities, and many engineers will not allow it. On the other hand the fuses for a 5 ampère circuit are so very fine that no damage can possibly be done to the finest flexible cord by overheating due to short circuit, provided it is protected by a suitable 5 ampère fuse. In most cases flexible cords are protected by fuses in ceiling roses and wall sockets, but the fuses in this case are on one pole only. The size of conductor employed for a 5 ampère circuit used to be a single 14 Standard wire gauge, but as it is not advisable to use single conductors, as before explained, a wire of 7/21½ is now nearly always employed, which is very nearly the same size. As the number of lights is reduced a 3/22 is used for 1 to 3 lights, and (excepting flexible cords) this is generally the smallest size of

conductor employed for electric lighting purposes.

In order to avoid having any joints made in conductors, some engineers so arrange the wiring that the conductors from each point of light are run right back to the sub-distributing boards. This system is extremely expensive, but is largely used in shipwork, where salt water is certain to find out any weak places in badly made joints. It is not usual to employ it in buildings on account of the cost and the multiplication of conductors it entails.

Alternating Currents.—The general arrangement of conductors and fuses applies to wiring for alternating currents much in the same way as for direct currents. It must be borne in mind, however, that if iron barrel is used to protect the wires it is usual to place *both* conductors in the same tube to avoid induction effects due to alternating currents, which, with heavy currents, would cause undue loss in pressure if each conductor were placed in a separate iron tube.

Arc Lamps and Motors.—Where arc lamps, either singly or in pairs, are employed, each circuit must have its own double pole switch and fuse on the distribution board. With direct currents, arc lamps require from 40 to 45 volts each to ensure steady running; it is therefore usual to put them up in pairs on 100 volt circuits, with a resistance in each circuit to absorb about 10 volts. A resistance is essential to the working of a direct current arc lamp as it acts as a regulator, and the more there is of it in circuit the better the lamps will work. It is therefore a very usual practice in mills and fac-

tories, where a large number of arc and incandescent lamps are used together at the same time, to fix the voltage at 110, of which the arc lamps absorb about 90 and the resistance 20. The power lost in the resistance is considerable, but the increased steadiness in the light more than compensates for this.

Arc lamps worked by means of alternating currents have this advantage over direct current lamps, that "choking coils" take the place of the

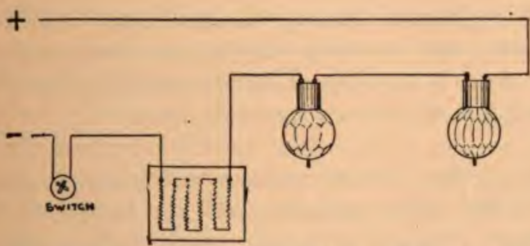


Diagram showing connections for two arc lamps in series.

resistances, and very little power is lost in these coils; but the amount of light given out by an alternating arc lamp is less than that given out by a direct current lamp taking the same current.

The diagram shows how the connections for direct current arc lamps are made for working two in series on 100 or 110 volt circuit. The connections for alternating current lamps are the same, the choking coil taking the place of the resistance.

Resistances and choking coils are always mounted

on insulators, and it is best to enclose them in well-ventilated iron cases, as they get hot when the current passes through them. Similarly the arc lamps themselves must be hung on insulators, and the working parts of the lamps insulated from the outer frame work, in order to avoid any possibility of earth connections being set up through accidental contact of the outer casing with metal connected to earth.

The same remarks apply equally to motors. If resistances are employed with them they must be protected and insulated, and the motors themselves should be fixed to strong wooden frame works by means of coach screws in such a manner that there can be no direct electrical earth connection between the bedplate of the motor and the earth.

NOTE.—Most central stations now supply electricity at 200 volts pressure, and arc lamps of the "enclosed" type are largely used. These lamps can be made to work at any pressure, from 80 volts upwards, so that they can be connected up either in single parallel on a 200 volt circuit, or two in series, but in each case either a resistance or choking coil must be inserted as above described.

CHAPTER IV

Jointing and Wood-casing System of Wiring

JOINTING.—One of the most important, if not the most important, part of the wiring of buildings is the making of proper joints in the conductors. Badly made joints are very likely to give trouble in course of time, although it may be years before the defects become apparent. Unfortunately, there are no means of detecting bad joints when once they have been concealed in the casings or tubes, and nothing is more annoying than to discover their existence after the completion of a building in which, perhaps, there are elaborate decorations and paintings. Many thousands of pounds have been spent in rectifying joints which have been discovered to be bad too late, and it cannot be urged too strongly that the utmost care should be exercised in the first instance in putting in work that is thoroughly reliable. To make good joints takes time and experienced workmen—any man can make bad joints and scamp the work, and it is hardly an exaggeration to say that in nine cases out of ten in

cheap and bad work the faults can be traced to bad jointing. Most engineers can show specimens of inferior joints taken from buildings where faults have appeared, and it is very interesting to note how moisture has in some cases made its way to the conductors, and in others how defective soldering has led to a break in the circuit or corrosion of the conductors due to the use of spirit as a flux, instead of resin. After joints are made and insulated, it is sometimes found that the insulation of the whole is not as good as it should be. This is probably due to allowing the outer braiding of the cables to come in contact with the conductors, in which case the insulation is at once lowered, as the braiding is a partial conductor and should be very carefully stripped back, thus exposing the vulcanized rubber, over which the pure rubber strip is subsequently wound.

In the case of small conductors, not larger than say 7/14, it is comparatively easy to make joints, but for cables larger than this it is not so easy. In fact, the work is somewhat of the same nature as splicing ropes, and just as difficult to perform neatly and efficiently. In the case of cables of large diameter jointing becomes a work of considerable difficulty, great skill being required to produce a really satisfactory result. No better description of the best method of making joints and insulating them can be given than the published instructions of some of the leading cable manufacturers, and the following illustrations and instructions are issued by Messrs. Verity, Ltd., of Birmingham :—

"First cut the taped or braided outer covering of the cable off for a distance of about 6 inches from the end of each cable. Next cut the vulcanized or pure rubber and other coverings at a distance of about $4\frac{1}{2}$ inches from the cable ends, and remove it entirely, leaving the conductor exposed. The $1\frac{1}{2}$ inches of rubber left standing should be neatly tapered with a sharp knife, as shown in the illus-

JOINTING.

FIG. 1.

trations. The strands are then separated ready for 'marrying,' as shown in Fig. 1, and the centre wire or core cut out. Before jointing all the wires must be most carefully cleaned with fine emery paper, and the body of the conductor tightly twisted together up to the point where the strands separate.

"The mode of 'marrying' the conductors is made plain in Fig. 2. The six strands of each cable pass alternately through those of the other. The con-

FIG. 2.—The Ends "married."

FIG. 3.

FIG. 4.

ductors are pressed together end to end, and the strands of one cable are twisted round the conductor of the other, and *vice versâ*. Care should be taken in twisting these to follow the same direction of turn as the body of the stranding in the conductor. The joint has now reached the stage shown in Fig. 3, and is ready for soldering. Resin only should be used as a flux, and the solder should be allowed to thoroughly permeate the joint. Rubber solution is next applied, and this should be rubbed evenly, in not too large a quantity, all over the surface of the joint, and of the exposed inner insulation. Pure rubber strip is now tightly bound in two layers throughout the whole length of the joint. A small allowance of india-rubber solution should be again applied to securely amalgamate the layers of tape. One or two layers of prepared or black tape are bound over all, and these again should receive an application of solution, the latter being well rubbed in The joint is then finished, and Fig. 4 affords a good illustration of its appearance.

"Joints in single and 3-strand wire are usually made in the ordinary 'twist' form, and then soldered and insulated as described above. 19, 37, and sometimes 61-strand cable is 'married' in the manner above described, the whole of the core being cut out, leaving only the outer strands. The cores are carefully butted tightly together, and the joint is proceeded with as above. Binding wire will be found useful in these cases for holding the large number of strands in place while the joint is made.

"In the case of a branch wire or cable being re-

quired to be tapped on to another of larger dimensions, there are two modes of joints in general use. One is on the T principle, and consists in tapping the branch conductor direct on to the main cable at the point where the off-shoot is required. The second is the parallel method, and is preferable in most cases, from being easier to insulate and other reasons. In making a parallel branch connection, the cable is stripped for about two inches at a point several inches further back than that at which the actual branch wire is desired to emanate. The end of the smaller conductor is stripped and cleaned for 6 or 8 inches and thrust between the strands of the cable. The latter is pinched tightly over the branch conductor, which is then wound strand by strand and tightened round the exposed portion of the cable. The insulated part of the branch wire is kept close to and parallel with the main cable until the point is reached where it is wished to take the direction of the tapping. It will be seen that this method makes it an exceedingly easy matter to arrange for the tapping to leave the main at the exact point required; and the actual joint, moreover, does not immediately face the outlet opening in the casing, as is the case where the direct T system is adopted.

"The insulation of the parallel branch joint is carried out in the ordinary way, care being taken to tape the insulated parts of main and branch conductors tightly together, and to see that the space between them is amply filled with good insulating material."

The following instructions are issued by the India-rubber, Gutta-percha and Telegraph Works Co., Ltd., for making joints in 19-strand and 37-strand cables :—

"For a 19-strand cable the conductor should be bared to a suitable length, and a small binder tied round the ends next to the rubber to keep the strand in place. The 12 outside wires should then be unstranded and turned back. The central 7-strand should then be soldered up and jointed as a solid conductor. To joint the 12 wires over this, every alternate wire should be cut off short, and the two sets of 12 married, that is, the long wire from the one end jointed to the short wire on the other, and so on round the central strand ; thus half the joints on the single wires will be on the one side of the joint in the central strand, the other half being on the other side. The joints in these single wires need not be scarfed, but only butted together at each end of the joint, where the long and short wires are soldered together, a narrow whipping of binding wire should be put on at each end and soldered, the whole being then filed down smooth.

"For a 37-strand cable the same method is followed out, with the addition that the 18 wires surrounding the 19-strand joint are married in the same way."

In certain cases, more especially in damp situations, it is advisable to vulcanize the joints so that the insulation throughout is homogeneous. The various cable manufacturers have different methods of carrying out the vulcanizing of cables, and special

insulating materials are sold for making vulcanized joints. Speaking generally, the process consists in heating the insulated joint to a temperature of nearly 300° Fahr., and maintaining this temperature for about half an hour.

The following instructions for vulcanizing joints are issued by the India-rubber, Gutta-percha and Telegraph Works Co., Ltd. :—

" When the conductor joint is finished, the rubber should be carefully trimmed and cut with as long a bevel as possible, according to the thickness of the rubber, the copper conductor and the bevelled ends should then be rubbed with pure benzole, and slightly heated with a spirit-lamp. The conductor and the bevel edges of the rubber should then be lapped with a pure rubber strip laid on as tightly as possible in one or two layers, according to size; this pure rubber should then be covered with special rubber solution, rubbed in so as to exclude air as much as possible; the joint should then stand until thoroughly dry. When the solution is sufficiently dry, and will not adhere to the fingers, the rubber strip should then be lapped on spirally, forming an uniform covering over the first coat of pure rubber, care being taken, by lapping tightly and evenly, to exclude all air. This rubber should be put on in two or more layers, until the diameter is equal to that of the original insulation, and over this a layer of tape strip should then be applied, the whole joint so made slightly exceeding in diameter that of the original insulation. When so completed, the next process is

that of vulcanization. To do this it is necessary to cover the joint with special sheeting cut to the whole width of the joint and firmly rolled round it, making a longitudinal seam, binding the sheeting over all by a strong cotton selvedge tape applied spirally, and as tightly as possible by hand. The sheeting thus will serve as a mould to keep the joint together during the process. The joint should then be fixed in the 'cure' (a cast-iron box) and the cover bolted on, to prevent damage to the original insulation, and to make the box tight, the insulation on each side of the joint, and at the proper distance to fit the cure, should be lapped with two or more coats of tape to cover the original insulation down to the point of junction. When the cure has thus been made tight, molten sulphur compound, previously melted in a suitable pot, should be poured into the cure round the joint, through the small hole in the top of the cure, and a suitable thermometer afterwards inserted in this hole to enable the temperature of the sulphur compound to be noted. This temperature should be kept as constant as possible between 290° and 300° Fahr. by means of a spirit-lamp.

"After the joint has been kept at the full temperature for about half an hour, the molten sulphur is run out, and the cure cover unbolted. The joint should then be taken out, the wrappings stripped off, and it will then be found to be vulcanized. A rough test of the degree of vulcanization may be made by trying with the thumb-nail (when the joint is cool) to indent it. If the mark of the nail

remains in the rubber, or if the rubber is too hard, the joint is a failure, and should be cut out and re-made. If the joint thus examined is found to be in good order, it should be finished off by lapping overall special tapes (No. 726), extending, say, over about two inches each side of the braiding; this taping to be then painted with shellac varnish.

"When insulating with rubber the hands should be kept dry and perfectly clean. When solution is used it should only be used in small quantities, and the spirit allowed to evaporate before the whole is again covered up. The spirit used should be of the best quality, so that it evaporates quickly, and leaves little or no residue behind. Special care should be taken that the rubber applied should be brought into immediate contact with the prepared ends, and that no tapes of the original insulation, or foreign material which would conduct moisture, should intervene between the two surfaces to be joined. Unless everything used is perfectly clean, and all air excluded by careful and tight lapping, the joint may be found to have blown, even though the rubber is properly vulcanized. Special attention therefore is directed to these points.

"If during vulcanization the temperature should drop below 290°, the heat will require to be maintained for a longer time; say if at 280°, the cure would last for about three-quarters of an hour instead of 30 minutes; but it is important that the temperature should be kept as constant as possible between the limits of 290° and 300° Fahr."

The accompanying illustration shows a "cure"

Cure for vulcanizing joints.

as used for vulcanizing joints for wiring work made by Messrs. W. T. Glover & Co., of Salford.

The apparatus consists of two pairs of heaters or cures (shown in the figure with handles) and four pairs of dies for accommodating cables up to 19/18s, also a thermometer registering up to 400°.

After the joints are made by the methods already described, the heaters are placed in an ordinary brazier's stove or over a fire until they attain a heat of 320° Fahr. This can be tested by inserting the thermometer in the aperture provided for the dies. If the thermometer registers over 320°, the cures must be allowed to cool. When the joint is prepared the dies should be fastened on securely, care being taken to see that they fit tightly. In order to "cure" the joint fix one set of cures on to the dies, and leave them on for 15 to 20 minutes, then replace with the second set heated as before. Small joints require 30 minutes, larger joints from 40 to 45 minutes.

Wood-casing System of Wiring.—Having described in the previous chapter the general arrangement of conductors in a building, it is necessary to enter more fully into the details of fixing and protecting the conductors.

By far the larger proportion of buildings that are wired have wood casings fixed to protect the conductors, and although many objections have been made to this form of protection, the fact remains that it still finds favour with most electricians, and appears likely to do so in the future where the conditions are favourable to its employment.

This system may be employed with advantage in dry situations, provided it is not likely to be subjected to severe mechanical injury. It is therefore extensively used in dwelling-houses and other buildings where these conditions prevail, and in spite of the rival claims of other methods which are being strongly put forward, it will probably hold its own on account of its cheapness and the ease with which it can be fixed. It also has this great advantage, that wherever it is run on the surface, it is quite a simple matter to get access to the conductors at any point in order to fix additional lights, or to alter the position of lamps or switches.

Wood casing consists of lengths of wood with grooves separated by a central fillet to take two conductors, and when these are placed in it a capping is screwed on. American whitewood is mostly employed for this purpose, as it is not greatly affected by change of temperature, and can be obtained without knots and flaws. It also has the advantage of being cheap. The casing and capping should be thoroughly painted inside and out with two coats of priming, and the capping fixed by screws, not nails.

The grooves should be large enough to admit of the conductors being easily drawn in and out when the capping is screwed on, and the following table gives the width of grooves to be employed for the more general sizes of conductors, assuming the insulating material to be of vulcanized rubber with the tape and braiding usually employed for 600 megohm cables :—

TABLE FOR SIZES OF CASINGS.

Size of Cable.	Width of each Groove.	Width of Casing.
3/22 7/21½	¼ inch	1½ inches
7/18 19/20	7/16 "	2¼ "
7/16 19/18	½ "	2½ "
7/14 19/16	⅝ "	3 "
19/14 37/16	¾ "	4½ "
37/14	1 "	5 "

For small casings the capping should be thicker in the centre than at the sides, and the screws fixed through to the centre fillet of wood; in sizes larger than 1¾ in. width the screws should be placed on the outsides of the grooves.

Under no conditions should casing be placed behind wet plaster or in damp places. A metallic covering of some description, such as composition tubing or iron barrel, should be used under such circumstances, as wood absorbs moisture very readily, and may thus give rise to considerable leakage through earth connections.

Workmen who have been trained as carpenters or joiners should be employed to fix casings and fuse-boards, as this work cannot be done efficiently by the ordinary wireman or with cheap labour. In buildings where inferior labour has been employed, it is not unusual to find lengths of casing come away from the walls, bringing with them switch and ceiling rose blocks, owing to the walls being plugged inefficiently, so that when changes

of temperature occur the plugs come out and the casings fall.

In order to avoid the dangers arising from short circuiting, great care should be taken that both positive and negative conductors should not be placed in the same groove in casings. Many engineers will not allow even two conductors of the same polarity to be placed in the same groove, although there may be no difference of potential between them. We consider, however, that "bunching" of conductors, as it is termed, in the same groove should be allowed, provided they are of the same polarity, for in this case no short circuiting can occur should the wires come in contact with one another. From an economical point of view it is advantageous to put several conductors in a groove, as the cost of labour is lessened, and in addition to this the mechanical strength of a larger casing containing many conductors is greater than that of a number of smaller casings laid side by side.

It must be remembered that that portion of a conductor between a lamp and its switch may become either positive or negative according to the position of the switch; that is, whether it is turned off or on. Thus, in the figure, if the switch is "on," the length of conductor between A and B is negative; but when it is "off," the connection to the negative source is broken and it becomes positive, as the connection to the positive source is still intact through the lamp, and a voltmeter connected across the terminals of the switch when in this

position would register the voltage of the installation. It is necessary therefore when "bunching" to remember that conductors between lamps and their switches may be either positive or negative, and should not therefore, theoretically, be placed in the same grooves, although the worst that could happen, should the wires come in contact, would not be a short circuit, but merely the connection

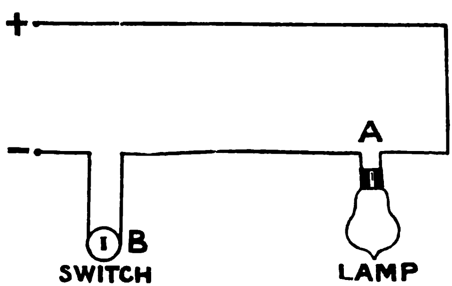


Diagram showing voltage on switch terminals.

of two or more circuits in such a way that each switch would not act independently of the others.

In order to simplify the wiring of houses, it is an excellent practice to employ cables of different colours for conductors of opposite polarity. Red and black are the colours generally used. It is then easy to arrange that all the switch wires shall be on one pole, and when testing for faults from the main switches it is easier to localize the faults.

When fixing the fuse-boxes, a description of

which will be given later, the casings should be taken right into the boxes and plenty of room allowed for the wires, so that the positive and negative wires cannot come in contact with one another behind the insulating panels. For this reason the insulating slabs should be well packed away from the walls, and all connections made in front of the boards. Badly designed fuse-boards are frequently a source of trouble, owing to the wires behind them being pressed together and bent at sharp angles.

Cleats.—In many mills and factories where power is available for electric light purposes, and cheapness is an object, the conductors may be fixed by means of wooden cleats, thus dispensing altogether with wood casing. This method has much to recommend it, provided always the fire risk is not a hazardous one and the insurance companies will pass the installation. The conductors can be very easily fixed in this manner and the labour bill much reduced. The cleats should not be used, however, unless the conditions are such that the conductors are not liable to injury. In cases where it is proposed to employ them, leave should first be obtained from the fire insurance companies interested. Teak or some hard wood is used as the material from which they are made, and the distance between the conductors must never be less than $1\frac{1}{2}$ inches.

CHAPTER V

Metal Tube and Concentric Systems of Wiring

IN these systems the cables, instead of being protected by wood casing, are drawn into ordinary tubes made either of iron or brass. The tube forms an excellent mechanical protection as it is waterproof and nails and screws cannot pierce it, but it is more expensive in first cost than casing, and when once it is fixed it is not easy to alter the position of the lights. At the present time iron barrel is more largely used than any other kind of tubing, and it can with advantage be employed in installations where the expense of wiring is not a first consideration, and nothing can be more suitable in buildings where it is necessary to have the wiring put in during the early stages of erection. In these cases the iron barrel can be fixed, and the wires drawn in afterwards by means of cords left for the purpose.

Instead of making joints in the tubing in the usual manner by T-pieces, special junction boxes

are provided, so that the cables can be drawn in in sections and the joints made in these boxes. The illustration shows a usual form of junction box with a lid, which is fixed with screws. The joints in these boxes are sometimes made in the ordinary manner already described, and sometimes by means of screwed clamps insulated from the metal of the box, and more frequently perhaps, by means of a grooved metal button resting on a porcelain in-

Junction box and lid.

sulator, in which case the ends of the conductors are soldered into the grooves of the button, and an insulating disc placed over the joint to prevent it making contact with the lid.

In new buildings many contractors put in the iron tubing before the plastering has been begun, and the conductors can then be drawn in after the decorations have been completed.

With long vertical runs of iron barrel (such as are frequently used up lift and air shafts) the whole

weight of the cables may press against the edge of the barrel at the top and chafe through the insulation. Precautions must be taken to avoid this by carefully fixing a good insulating material between the cables and the edge of the tube.

Where the iron barrels enter the fuse-boxes, nuts and washers must be placed on both sides of the outer case of the boxes to make the joints water-tight, and wherever possible the bends of the barrel should be made as easy as possible.

It is usual to draw both positive and negative conductors into the same tube, and many engineers consider the mechanical protection so good that they allow the use of comparatively lightly insulated conductors, as these are, under the circumstances, quite as serviceable as those of higher insulation, provided always that sufficient care has been taken in drawing in the conductors in such a manner that mechanical abrasions are avoided.

An objection sometimes made to the use of iron barrel is that moisture condensing in the interior may impair the insulation of the cables, and to avoid this, and at the same time provide a smooth inner surface free from burrs and projections, an insulated lining is manufactured by some firms consisting of wood or special insulating material. The expense of using tubing of this description is considerable, and it is doubtful for this reason if it will come into very extensive use.

A new system of steel tubing has lately been introduced, known as the "simplex" steel conduit. This tubing is much cheaper in first cost than any

other, and at the same time easier to fix ; it is therefore commanding a large sale.

The tubes are formed of thin steel covered with a coating of enamel inside and out to prevent rust, and at the same time present an insulated surface to the cables. The following table gives the sizes in which the tubes are made, also the thickness of the metal and the weight per 100 feet run :—

SIMPLEX TUBES.

Approximate external diameter in inches . .	½	⅝	¾	⅞	1	1¼	1½	2
Exact external diam. in inches	·51	·64	·77	·88	1·01	1·25	1·5	2
Exact internal diam. in inches	·42	·54	·67	·77	·89	1·13	1·48	1·87
Weight in lbs. per 100 feet . .	19	24·5	32	43	51	84·5	101	132
Standard Wire Gauge . . .	20	20	19	18	18	16	16	16

The tubes can be cut either by means of a hacksaw or by filing, and the ends after cutting should be carefully smoothed.

Fig. 1 shows a T-piece, and the method of jointing the tubes. It also shows a reducing nipple fixed into the vertical arm of the T-piece. From the sectional view it will be seen that the tubes fit closely into the T-piece, and abut against a shoulder made for the purpose ; no fitting or screwing is required, nor is the sectional area of the passage

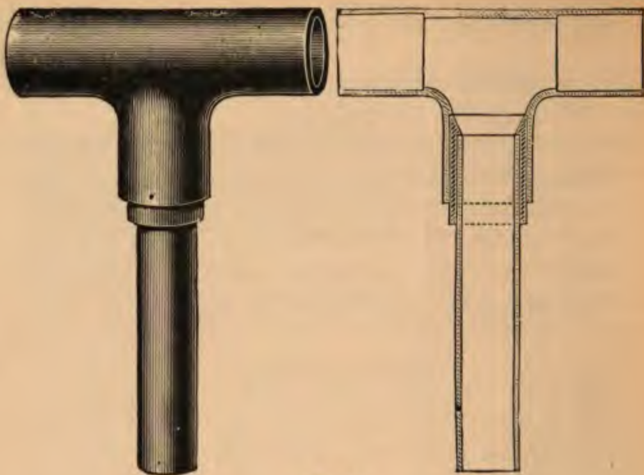


FIG. 1.

F G. 2.

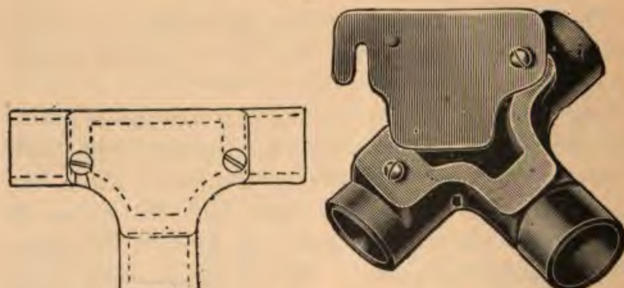


FIG. 3.

reduced at the joint; similarly, the reducing nipple

Fig. 4.

Fig. 5.

is provided with a shoulder on the inside, so that the smaller tube can be pushed up against it.

Fig. 2 shows what is called an inspection bend; it is provided with a lid in order that joints can be made and inspected at any time if necessary. Fig. 3 shows an inspection T-piece made on the same lines.

Junction boxes are made to suit the various com-

Fig. 6.

binations required for wiring purposes, and different forms of these are shown in Figs. 4, 5, and 6.

It cannot be said that this system of tubing is absolutely water-tight; it is very nearly so, however, and might well be employed in any situation under cover.

To a certain extent it is possible to bend the tubes cold; this can be done by boring a hole in a piece of hard wood about 2 feet long × 2 in. × 3 in.,

threading this on the tube and using it as a lever to produce the desired bend. This method must not, however, be employed on tubes of greater diameter than $\frac{3}{4}$ in.

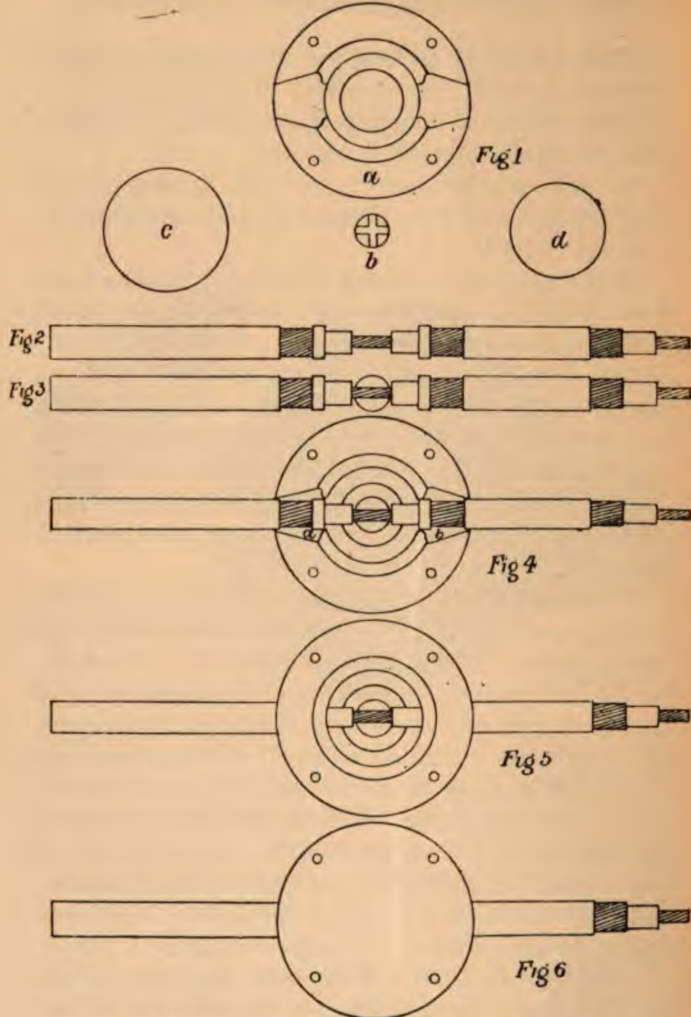
It may be mentioned that a $\frac{5}{8}$ in. tube will take four cables of 3/22, and one of $\frac{3}{4}$ in. will take no less than eight.

If the cables are drawn in after the tubes have been fixed, it must be remembered that they should not be drawn past more than two bends at a time.

Other descriptions of tubing are used, such as Muntz metal and brass tube, in which case each conductor is usually run in a separate tube; and there is also a system in which the tubes are made of compressed paper, special brass end fittings being employed for junctions and for fixing into junction boxes.

Concentric Wiring.—In systems termed concentric both the conductors are contained in one cable, only one of which, "the inner," is insulated. The other, called the "outer," consisting of stranded wires, is laid concentrically over the insulation of the inner, and forms the "earthed return," which means that no precautions are taken to insulate the outer conductor from the earth. Manufacturers of concentric apparatus employ various kinds of cables, and in some cases a metal tube is used as the earth return, the inner conductor being drawn into it, and consisting of an ordinary vulcanized cable.

From the above it will be seen that as only one of the conductors is insulated, the difficulty of obtaining good insulation tests is much lessened; and



Concentric system junction box connections.

as all switches and fuses are placed on the insulated wire only, these are made single-pole instead of double-pole, a great gain in simplicity, as every switch and fuse is something liable to get out of order, and the more these pieces of apparatus can be reduced in number the better.

In the fittings the inner conductor only is taken to the holders, the connection to the outer being made either by the metal of the fitting itself, if it is of the nature of a bracket, or else by a special copper-braided flexible cord, if the fitting is a pendant. It will thus be seen that the outer forms one complete metallic conductor throughout the system, completely enveloping the inner conductor in a water-tight manner; and since it is purposely "earthed" at convenient points it is impossible that any shock can be received from it. As regards danger from fire this system is the safest, inasmuch as any sparks or arcing due to the electric current must take place inside the outer conductor, and as the air cannot enter, the worst that could happen would be a partial melting of the cable, and this would be an impossibility with carefully arranged fuses.

The chief objections at present to the system are, first, that the cost of the materials is higher than those used with wood-casing systems, and, secondly, supply companies using direct currents will not allow any installation "earthed" on one pole to be connected to their mains. This is owing to the fact that should an "earth" on the opposite pole be developed anywhere on the system of network

(which includes in most cases many hundreds of miles of cables) short circuits would be set up and lead to serious trouble. This objection does not apply to the same extent with companies supplying alternating currents, as transformers can be employed for any special installation, and an earth on the secondary of the transformer would not be transmitted to the high tension mains. No doubt as concentric wiring comes more into vogue, as it is certain to do, the cost of the materials will be reduced.

Mr. Andrews, of Putney Bridge, Fulham, and Messrs. Mavor & Coulson have been the chief pioneers in concentric wiring. In principle their systems are the same, but in detail the developments have been carried out on different lines.

In Messrs. Mavor & Coulson's system no cable smaller than a single 14 gauge or 7/21½ is used, and for lighting these cables are used for 5 ampère circuits starting from the distributing boards. The outer conductor consists of copper strands wound spirally over the insulation, and over this a lead sheathing is drawn to make the whole water-tight. In order to protect the cable further, an armouring of galvanized iron wires can be used over the lead, but in the majority of cases for small cables this is not necessary. All the cables used in concentric wiring are flexible, and can therefore be easily bent round corners where necessary.

Messrs. Mavor & Coulson issue the following instructions for jointing their cables :—

Instructions for Making Joints.

A. Prepare the cables as shown in Fig. 2, p. 70, as follows :—

(1) Cut away the lead sheathing and the outer conductor from a length equal to the diameter of the central chamber of the junction box.

(2) Remove the insulation to expose a sufficient length of the core to allow of the central contact button (*b* Fig. 1) being soldered to it.

(3) Remove the lead sheathing to expose the copper of the outer conductor at the points corresponding with the jointing pockets of the junction box, but leave sufficient lead sheathing projecting into the pocket to ensure its being properly jointed thereto. An angular strip of lead sheathing, one-eighth inch wide, should be left to fill the opening to the central chamber and prevent the solder flowing into it.

(4) If the outer conductor is not already tinned, the parts exposed for the jointing pocket should be carefully tinned.

B. Solder the contact tip to the inner conductor as shown in Fig. 3.

C. Lay the conductor into the junction box as shown in Fig. 4.

D. Fill the pockets (*a* and *b* Fig. 4) with solder, using resin as a flux. A heavy soldering bolt, a

melting pot and small ladle, or a jointing lamp may be used (a jointing lamp is to be preferred, except for large junctions), and care must be taken to heat the junction box sufficiently to make the tinning of the jointing pockets run.

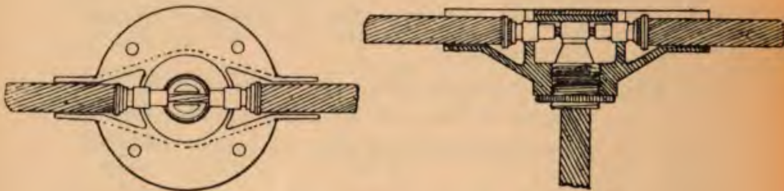


FIG. 1.

E. Lay the insulating disc (*c* Fig. 1) in the central chamber of the junction box.

F. Lay the tinned brass disc on the back of the junction box (*d* Fig. 1) in the tinned recess provided for it, and solder it to the box. The junction is then complete.

The above describes the process of making a throughway junction tapped for a fitting; and all other junctions, whether tapped for fittings or blind, are similarly effected.

When joining armoured cables, each strand of the armouring should be separately tinned before the cable is placed in the junction box.

Fig. 1 gives a plan and section of the junction box showing the insulating air space. The boxes are made of cast brass, tinned all over, to facilitate soldering, and it will be noticed that

in making branches for pendants the inner conductor is not broken, and long lengths of the cable can be tapped at any desired points without cutting the inner conductor, provided switch-holders are used for the lamps, as is generally the case.

Fig. 2 shows a variety of junction boxes, in plan and elevation, used for 1, 2, 3 or 4 ways, and made so that fittings can be attached to them or otherwise.

Fig. 3 shows a main switch-board in which all the switches are placed on the inner conductor, which enters at the bottom and leaves in 4 circuits at the top. It will be noticed that the outer conductors are all connected together by a rectangular copper frame.

A 4-way distribution box and pendant circuit are shown in Fig. 4. These boxes are usually made of

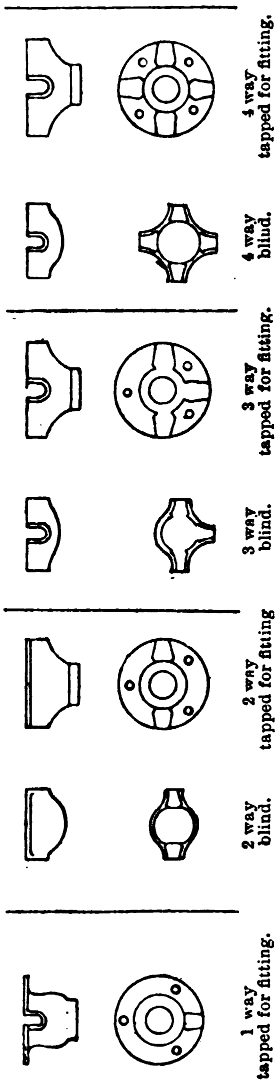


FIG. 2.

iron. The inner conductor enters the box and is

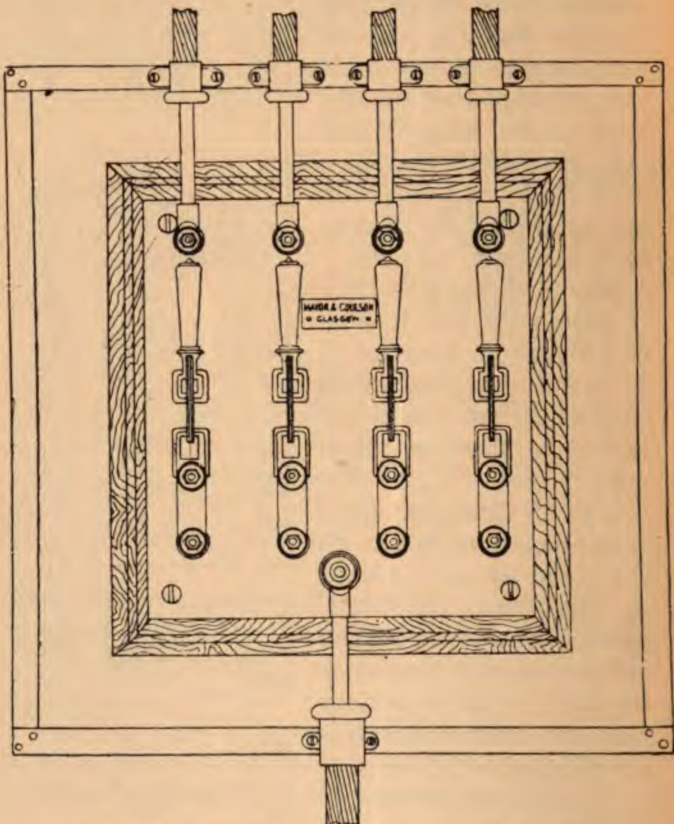


FIG. 3.—Main switch-board for concentric system.

soldered to the copper bar, from which the 4 circuits are taken through the fuses. The fuse blocks are

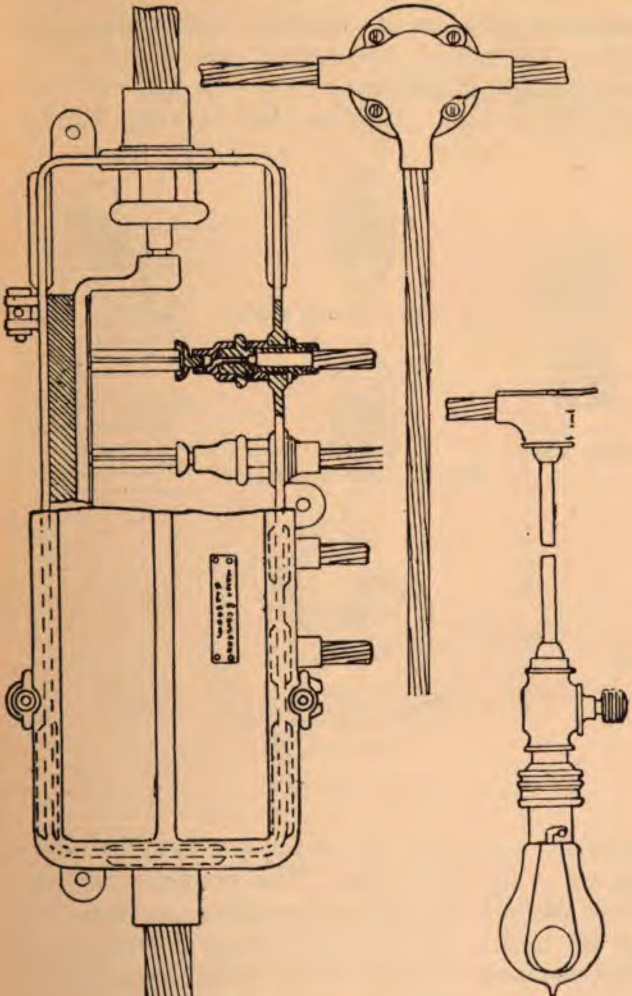


FIG. 4.—Subdistribution fuse.

porcelain cylinders of U section with countersunk ends. The contact tips rest in these countersinks, and are held in position by the fuse wire, which is soldered to them. The fuse-block is readily fixed in

Fig. 5.
Double nipple.

Fig. 6.—Top nipple for pendant.

Bottom nipple for pendant.

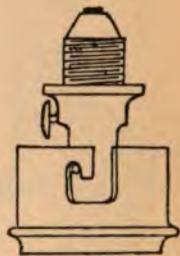


Fig. 7.
Gimbal fitting.

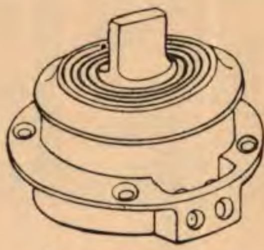


Fig. 8.—Switch.

position or released by operating the milled screw shown in the illustration. The branch conductors leave the box through sockets similar to those used for the mains. The branches being of uniform section, the fuses are uniform and interchangeable.

With this system central contact incandescent

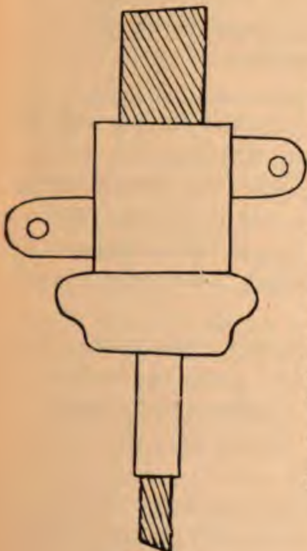


FIG. 9.—Switch-board negative bar terminals.

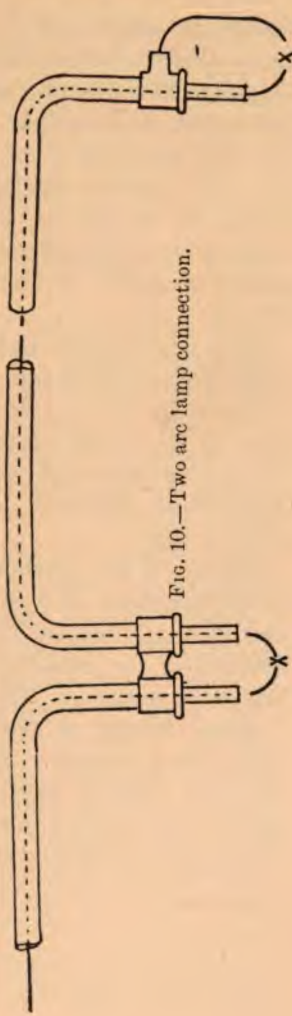


FIG. 10.—Two arc lamp connection.

lamps are used, and the lampholders consequently have a single central contact. Fig. 5 shows a double nipple to fit a junction at one end and lampholder at the other, and pendant nipples are shown in Fig. 6, the top being used for screwing into the junction box, the bottom nipple for the holder being connected to the top by means of a flexible cord. In cases where electroliers with brass tubes are employed a gimbal fitting is employed, illustrated in Fig. 7.

In order to show how the details of this system have been worked out, an illustration of a switch is given in Fig. 8. In this case the metal rim is used as the outer conductor. It is unfortunate in this system that *both* conductors must be brought to any switch although the switch connections only require one.

In Fig. 9 the method of making the connection to the terminal of a switch and earth bar is shown, and in Fig. 10 a somewhat similar arrangement is illustrated for making the connections for 2 arc lamps in series on 100 volts.

Brass tubing is now being employed to some extent as a protection for cables, and in many cases the tube itself is used as the return conductor, in which case junction boxes somewhat similar to those already described are used.

CHAPTER VI

Electrical Accessories

HAVING described the various systems of wiring at present in use, the various accessories, such as cut-outs, ceiling roses, switches, etc., used in installation work must be described.

Chief of these are the fuses and fuse-boards. As mentioned in a former chapter the current in any circuit, before it reaches a lamp, or group of lamps, has to pass through a piece of easily fusible metal, usually a mixture of lead and tin, and if any marked excess of current occurs the fuse at once "blows" or melts, automatically cutting off the current. Now in order to put in the right size fuse wires it is necessary to know the currents at which they will melt. Unfortunately, however, it is not an easy matter to arrive at definite rules, as a given fuse wire will melt at different currents under varying conditions; thus temperature, length of wire, size of terminals of the fuses, and contact surface, all influence to some extent the melting current of the fuses, and in addition to this oxidation and disintegration of the fuse wire play an important part in determining how long a fuse will last.

Long lengths of a given fuse wire will melt at a certain current, within small limits, under the usual conditions of temperature; but in practice lengths of only an inch or two are used, and then the size and shape of the terminal exercise a modifying influence on the melting current, and a fuse wire that in 1 yard lengths might carry, say, 5 ampères, would in 2 inch lengths carry, perhaps, double that amount of current, as the heat developed would be carried to the terminals and the copper wires, and thus be quickly dissipated.

In order to arrive at the melting current of uses, as actually used, direct experiments must be made with the fuse wire made up and fixed to the terminals of the fuse in which it is to be used, then known currents are passed through until the melting current is reached and recorded. It is quite useless to buy what is known as, say, 5 ampère fuse wire, then to attach it to the terminals and expect it to melt at exactly 5 ampères.

Most makers now sell fuses already made up with fuse wires adapted to currents from 5 to 100 ampères, and the melting currents are ascertained experimentally before being sent out, so that reliance can be placed on their melting with about the right currents.

Many engineers specify that fuses shall melt at about 50% current in excess of that which the circuit will carry when fully loaded; thus a 5 ampère fuse should melt at 7½ ampères and a 10 ampère fuse at 15 ampères.

For large main fuses it is a good rule to so ar-

range the size of fuse wire that, with full load current, the fuse becomes just warm to the hand, the terminals remaining cold; under these circumstances any large excess of current would at once melt the fuse.

Under no conditions should the terminals of a fuse be allowed to become hot, otherwise the fuse

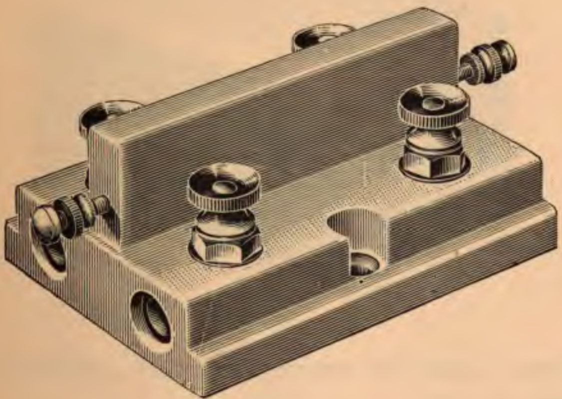


FIG. 1.

wire does not get a fair chance of dissipating its heat, and is likely to melt with too low a current, with the result that, in all probability, a copper wire will be inserted, which will not melt at all, and is a source of danger instead of a protection.

For fuses carrying large currents pure tin is largely employed, and is not easily oxidized, and being fairly hard can withstand the pressure of

the clamping screws of the fuse terminals. It may be mentioned here that large fuses are seldom made to melt at 50% excess current. For short periods a large excess of current can always be passed through a large fuse, as a sensible period of time

FIG. 2.

elapses before the temperature rises sufficiently to melt the wire.

Figs. 1 and 2 show a double-pole porcelain fuse for about 10 ampères, such as is often used for fixing direct on to casings, and Fig. 3 illustrates a larger main fuse enclosed in a cast-iron case with thimbles for the cables projecting through insulated glands in the case. This type is much to be recommended for damp situations.

In order to serve as a guide for determining approximately the sizes of fuse wires that may be employed for cut-outs, the following table gives the

melting currents of various gauges of a special fuse wire as made by Messrs. W. Glover & Co., Ltd., of Manchester :—

FUSIBLE WIRE FOR CUT-OUTS.

According to Sir W. H. Preece's Table.

Approximate S.W.G.	Diameter.	Current required to fuse.
	Inch.	Ampères.
8½	0·1548	100
9·0	0·1443	90
9½	0·1333	80
10·0	0·1220	70
11·0	0·1101	60
12½	0·0975	50
13·0	0·0909	45
13½	0·0840	40
14½	0·0769	35
15·0	0·0694	30
16·0	0·0614	25
17·0	0·0529	20
19·0	0·0437	15
21·0	0·0334	10
25·0	0·0210	5
26·0	0·0181	4
28·0	0·0149	3
31·0	0·0113	2
36·0	0·0072	1

Fuses are generally grouped together and placed in cases with glass fronts, the mains being soldered to straight bars of gun-metal or copper, to which

the fusible wire for the branch circuits is connected. Figs. 4 and 5 show a very good type of fuse-box and fuse as made by Messrs. Verity, Ltd. In this the fuses are easily replaceable, and each fuse is marked with the current it has to carry; it will be noticed that the fuses are placed on each pole.

FIG. 3.

Main Switches and Fuses.—These are used to control all the lights in a building, and are usually double-pole; that is, there is a switch and fuse to each pole, the switch handles being so arranged that one movement controls both switches. The essential requisites of a good switch are, good and strong mechanical construction, ample contact surfaces and sufficient

Fig. 4.

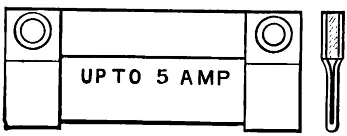


Fig. 5.

Types of Fuses.

metal for a current density of not more than 250 ampères per square inch, and a quick break. It is usual to mount the working parts either on enamel-

FIG. 1.—Switch-board with fuses.

led slate or porcelain, and if two switches are connected together by a common handle-bar each switch

should be mounted on a separate base. The handle must, of course, be insulated, in order to prevent any possibility of shocks. Figs. 1 and 2 show very good specimens of a 4-way switch-board and double-pole switch and fuse.

FIG. 2.—Main double-pole switch and fuse.

Branch switches for controlling single lights or small groups of lights are usually single-pole, and should be made on much the same lines as the larger switches. Fig. 3 shows the now well-known Tumler switch, and in Fig. 4 an ordinary porcelain switch is shown. In damp situations the Tumler switches should not be used, as they have metal

covers, and should one of the terminals touch the cover the handle would no longer be insulated.

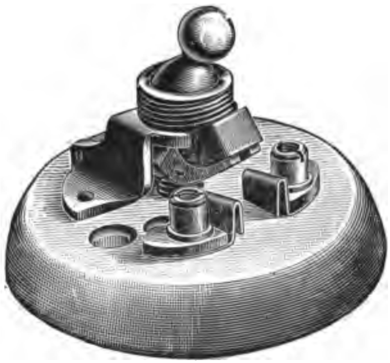


FIG. 3.—Tumler switch.

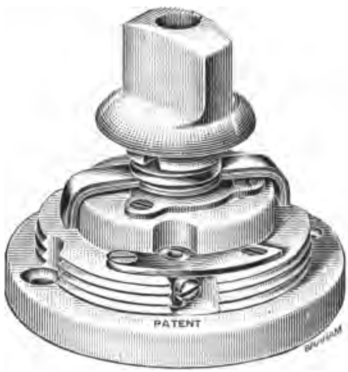


FIG. 4.—Porcelain switch.

Two-way Switches.—These are largely employed in cases where it is necessary to control a light from

two points. Fig. 5 shows diagrammatically the connections and method of employing these switches; Messrs. Verity, Ltd., make a very neat switch of the Tumler pattern for the purpose, and this is

FIG. 5.—Diagram showing connections for two 2-way switches.

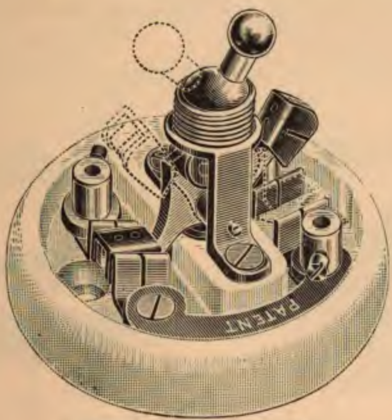


FIG. 6.—2-way swit h.

illustrated in Fig. 6. There are three terminals, as in the diagrammatic sketch, but two only are seen in the figure, as the third is behind the handle.

The principle of 2-way switches may be further developed so that a light may be controlled from

three or any number of points by employing switches with four terminals. The connections in the figure are, in Fig. 1, shown for controlling a light from 4 points altogether. The arrangement looks at first sight complicated, but the two centre switches are

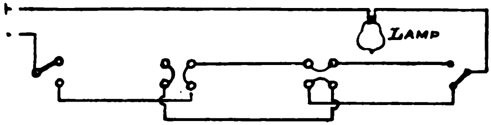


FIG. 1.—Diagram showing connections for controlling a lamp from four points.

merely commutators for changing the current from one wire to the other.

Ceiling roses are usually made of porcelain, and

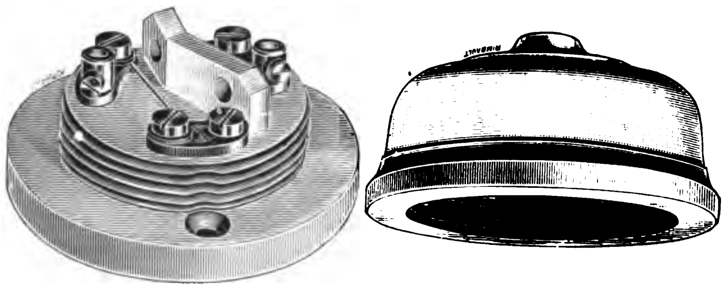


FIG. 2.—Ceiling rose and cover.

used in conjunction with ordinary pendant fittings for the purpose of making a neat and satisfactory junction between the stranded conductors and the flexible cords of the fittings. With ordinary pressures of 100 volts or less, a fuse is generally introduced; a good type is shown in Fig. 2.

It is often convenient to have an arrangement by which a flexible cord can be easily connected to the conductors for portable or standard lamps. Such an arrangement is called a wall socket, and consists of two parts, one fixed to the conductors and the other detachable. Fig. 3 shows one of the many

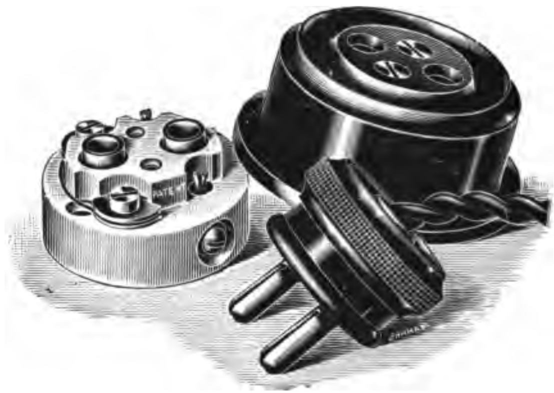


FIG. 3.—Wall socket.

forms of these sockets. In the fixed portion the conductors are led to two terminals, a fuse being placed on one pole, and in the detachable portion the flexible cord is attached to two prongs of metal, which engage with the two tube pieces of metal in the fixed portion when the plug is thrust into the socket. Fig. 4 shows another form of wall socket.

In order to secure good insulation and a good fixing for ceiling roses, switches and wall sockets, these pieces of apparatus are in most cases mounted

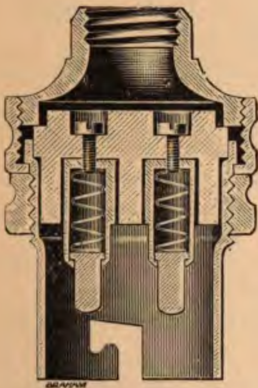
on hard wood blocks recessed at the back to allow room for the conductors.

Good lamp-holders are an important part of every installation. Each holder consists of several parts

FIG. 4.—Wall socket.

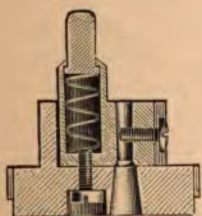
shown in the accompanying illustrations, the final contact to the lamp terminals being made by two plungers, or " bayonets," actuated by springs. The terminals are encased in porcelain, which is pro-

tected by outer coverings of brass, screwed together by a ring, as shown. If a shade has to be fixed to the

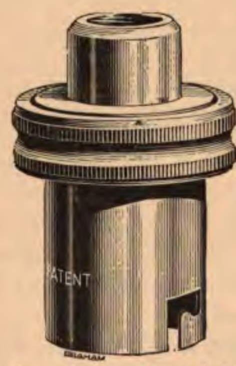


Section of ½″ bayonet lamp-holder with shade-carrier ring.

End view of holder.



Sectional view of bayonet, showing terminal for conductor.



General view of lamp-holder.

holder an additional ring is put on, called the "shade-carrier." The holder as shown is made by Verity,

Ltd., the details of the plunger being given. If the holders are to be attached to a bracket a screwed end is left, as shown, but for use with flexible cords a so-called "cord-grip" is used, by which the flexible conductors are held, so that no strain can be put on the terminals of the holder.

Other forms of holders are largely used, especially in foreign countries, but the bayonet type is at the present time almost exclusively used in England. The illustrations given are full size; smaller sizes are used for candle fittings.

Flexible cords, which are so largely used with pendants and portable lamps, are made up of a large number of very fine stranded copper wires to each conductor. For ordinary work a flexible cord for a 16-candle-power lamp should have thirty-five wires of No. 40 gauge in each conductor, and the insulation should consist of pure and vulcanized india-rubber, and a protecting covering of silk or cotton. The public cannot be too strongly cautioned against using cheap flexible cords, of which vast quantities are imported from abroad. Unless they are thoroughly well made they are a source of danger, as the two cords are twisted together, and it is easy for the two conductors to come together if the insulation is in any way inferior. Particular attention should be paid to flexible cords when pressures of 200 volts and over are used.

Wiring Fittings.—It is a very important matter to have all electric light fittings properly wired. Earth connections and short circuits are of daily occurrence in fittings which may be excellent from

an artistic point of view, but are not properly adapted for electric light purposes, and it is often surprising to see how badly the wiring of fittings is done by the makers of the fittings themselves. In the manufacture of fittings far too little attention is paid to making adequate provision for drawing in the wires, and in many cases it is impossible to get them through the tubes without injuring the insulation. The two chief essentials for good wiring are (1) that no roughness or burrs should be left in the tubes to cause abrasion, and (2) that the tubes should be of sufficient diameter to take the wires without undue crushing.

In wiring ordinary brackets the cables from the walls should be left long enough to reach the holders of the fittings so that jointing is unnecessary. Now in order to arrange for, say, two cables of 3/22 to be pushed through the bracket tube easily, the internal diameter should be about ½-inch. If 3/8 tube is used, and the shape of the bracket is curved, it may be necessary to use either a flexible cord, or a specially made cable of small diameter, and in either case joints have to be made which have to be stowed away at the base of the fitting, and are frequently injured during the fixing of the fitting.

When fittings are adapted for electric light purposes it is often impossible to avoid the use of flexible cords, and whenever these cords pass through metal in which holes have to be drilled, an ebonite bush should be placed in the hole to prevent any chance of short circuiting.

When wiring chandeliers with flexible cords, the connection to the conductors should be made if possible by means of a ceiling rose, and in no case should flexible cord be taken through the plaster of a ceiling without adequate protection.

On no account whatever must gas-fittings be adapted for electric light purposes when connected to the gas mains; any connection between the conductors and the fitting would at once cause a direct earth connection, which would lead to trouble of a serious nature. In all such cases the gas supply must be cut off entirely from the fitting, which must itself be insulated, either by a hard wood block or other arrangements designed for the purpose.

In many fittings, such as large chandeliers, groups of candle fittings have to be wired. In order to avoid joints in the conductors the connections can be made by running the wires to the terminal of one holder, and then connecting the holder next by means of wires taken from the terminals of the first holder; this is known as "looping" from holder to holder. Difficulties arise sometimes in cases where small lamps must be used and the pressure is high, say 200 volts; for small lamps cannot yet be made satisfactorily to withstand pressures of 200 volts.[1] In such cases two or more lamps must be run in series. Suppose, for instance, it were necessary to wire a 7-light candlestick, the pressure being 200 volts; it would be advisable to use one series of three 66-volt lamps, and two series of two 100-volt lamps. This is a somewhat awkward combination, but until

[1] Small lamps of 5 c.p. are now made for pressures of 200 volts.

Fig. 1.

Fig. 2.

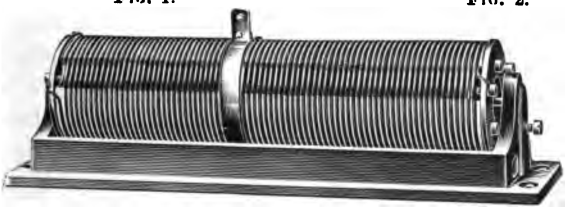


Fig. 3.

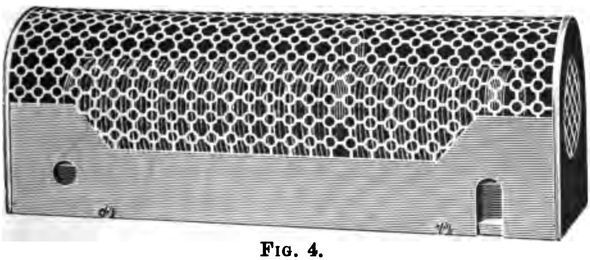


Fig. 4.

Resistances.

200-volt lamps can be obtained in all sizes and candle-powers, combinations of this description have sometimes to be used.

When motors or arc lamps are fixed, great care must be taken to so arrange the resistances that they cannot give rise to a fire; they must be well insulated from earth, and should be preferably enclosed. Figs. 1, 2 and 3 show different kinds of resistances in use at the present time. Two of these are arranged to work with handles to cut the resistance in or out, and one has a movable ring contact. This is a usual form for arc lamps, as the contact is not likely to be moved when once it has been set for the right current.

Employment of 200 *Volts Pressure.*—Many of the large supply companies are now supplying current at 200 volts pressure instead of 100 volts as before; and in order to deal satisfactorily with the increased pressure it has been found advisable to make a few alterations in the designs of switches and fuses. Such alterations are not absolutely necessary, provided the designs were good for 100 volts, and generally speaking it may be stated here that any installation properly wired for 100 volts will stand the increased pressure, and work satisfactorily without any alteration to the wiring beyond changing the lamps and putting in fuses of half the capacity in ampères, as it must be remembered that, as the pressure is doubled, the quantity of current consumed is one half. It must be remembered, however, that should a short circuit occur with 200 volts, the effects are likely to be more dangerous

than if 100 volts are used. For this reason modifications are made in the designs of the fuse-boards: the distance between the terminals is increased, and in order to avoid anything in the shape of a permanent arc (which might easily be set up with a pressure of 200 volts) a ridge of insulating material is put between the terminals of the fuses, and

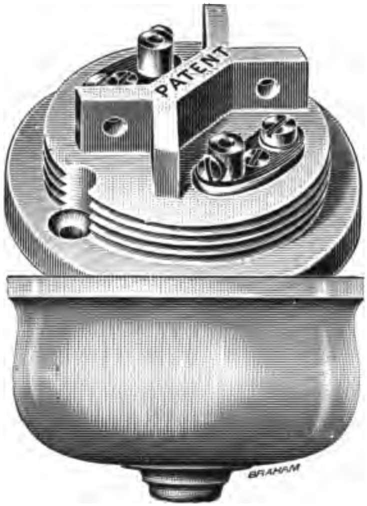


FIG. 5.—High tension ceiling rose.

the fusible wire bent over this; then, in case a short circuit occurs, an arc cannot be maintained because the direct line between the terminals is interrupted by the insulating ridge. Again, in order to prevent the harm due to sudden expansion of the air when a fuse melts, it has been found advisable to ventilate

all fuse-boxes, thus allowing a passage for the air. In order to illustrate the insulating ridge above referred to, a ceiling rose is illustrated in Fig. 5, showing the method employed for avoiding permanent arcs. As it is somewhat difficult to ventilate ceiling roses and wall sockets and switches with fuses, *no fuses at all should be placed* in these pieces of apparatus; all fuses are then confined to the fuse-boards, where there is plenty of space and ventilation.

Many engineers advise an increased break for use with 200 volts, and with heavy currents this is no doubt advisable, but with small switches for two or three incandescent lamps it is hardly necessary, as the currents are very small.

CHAPTER VII

Testing

WHEN the wiring of a building has been completed, certain tests can be applied which will, to some extent, show if the work has been carried out properly. Unfortunately, there are no tests that can with certainty detect bad joints, and it frequently happens that in a badly wired house the tests come out much better than in an installation that may be considered perfect, and in which a much greater amount of care and expense has been expended. In a building that is perfectly dry, and where earth connections are not likely to occur, it is almost impossible that any test should show inferior insulation, and the wiring in such cases may work satisfactorily for an indefinite period, but should water or moisture at any time gain access to the conductors, inferior work will at once be attacked owing to electrolysis, and the wiring throughout under such circumstances is a perpetual source of danger and annoyance. Such faults, when once developed by electrolysis, are immediately detected by instruments, and can be located. In damp situations, on the other hand, it is most difficult to obtain perfect insulation tests, even if great care

has been taken with the wiring; a slight film of moisture connecting any part of the metal conductors to the earth being quite sufficient to lower the insulation resistance to such an extent that the standard fixed by the rules of the supply company is not reached, and the insulation resistance must be raised before the current connections are made.

It is impossible to insulate the wiring of a building absolutely. Under the most perfect conditions very delicate instruments could detect slight leakage across the insulating substance of the conductors; it therefore becomes necessary to fix some limit to the amount of leakage that may be allowed; or, in other words, to fix what is known as the insulation resistance to earth. As no substance in existence is a perfect insulator, the insulation resistance must depend upon the length and surface of the conductor exposed to the insulating substance, and in the case of electric cables the manufacturers use as their standard the insulation resistance per mile of conductors. In a good cable, in which the insulation consists of vulcanized rubber, the guaranteed resistance per mile will vary between 300 and 2,000 megohms per mile. The wiring, therefore, in a building, where, say, one mile of conductor is used, should have an insulation resistance of several hundred megohms. Tests, however, are generally carried out when all fittings, switches, etc., are fixed, and it is on these that moisture is likely to collect, and thus lower the insulation resistance. Under these circumstances certain empirical rules for standards of insulation have been devised by

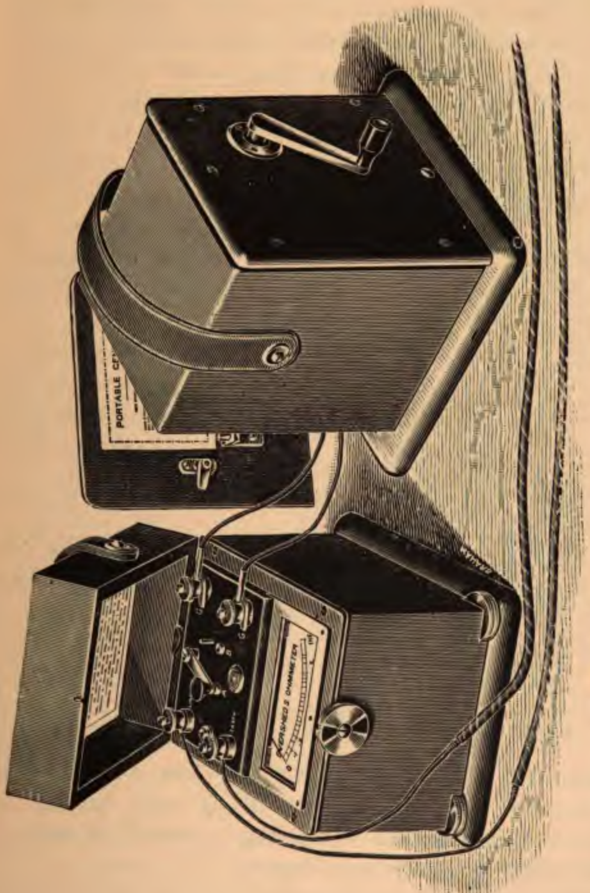


FIG. 1.—Ohmmeter and generator. Evershed's patent.

supply companies and consulting engineers, and they take the form of allowing certain insulation resistances to earth in proportion to the number of lamps installed. According to the wiring rules of the Institution of Electrical Engineers, the standard taken is that the insulation resistance to earth, of any entire installation, be 10 megohms divided by the maximum number of ampères required for the lamps and other appliances. Thus, a 100-light installation, taking a maximum of 60 ampères, should have an insulation resistance to earth of $\frac{10}{60} = \cdot 16$ megohm. Tests for insulation resistance to earth are usually carried out by a set of instruments known as an ohmmeter and generator. These are illustrated in Fig. 1. The generator consists of a small dynamo turned by hand, and capable of giving a small current at 100 volts or more if necessary.

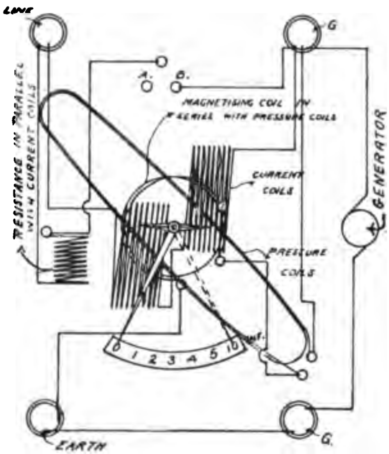


FIG. 2.—Diagrammatic sketch of connections of ohmmeter and generator.

The dial of the ohmmeter is graduated in megohms and fractions of a megohm, the generator being connected to two of the four terminals, as

shown in the illustration, the remaining two terminals being connected to the wiring to be tested and the "earth" (usually a gas or water pipe).

Fig. 2 shows a diagrammatic sketch of the connections inside the ohmmeter. The pointer on the dial (Fig. 1) is attached to a soft iron needle below the dial in the interior of the instrument, and is actuated by two sets of coils, called the "pressure" and "current" coils, shown in Fig. 2.[1] The pressure coils magnetize the needle, and cause it to lie in such a position that the pointer indicates "infinity." The current coils are so arranged that if a current passes in them the needle is moved, and the pointer with it, towards zero on the dial. If now there is no resistance between the line and the earth terminals (or, in other words, if there is a dead "earth" connection) a comparatively large current will pass through the current coil, and the pointer will indicate zero; on the other hand, if the insulation between the line and the earth is above 5 megohms, the needle will scarcely be moved, and the pointer will indicate "infinity." Readings between these two can be taken indicating the insulation resistance to earth.

The instrument is so arranged that, by placing the small handle on *B* instead of *A*, such a resistance is inserted in parallel with the current coils

[1] In the latest instruments there is, in series with the pressure coils, a magnetizing coil surrounding a soft iron core, pivoted vertically on the top of which the soft iron needle is fixed; this needle is therefore unipolar, and tends to set itself at right angles to the axis of the pressure coils, if no current is passing in the current coils.

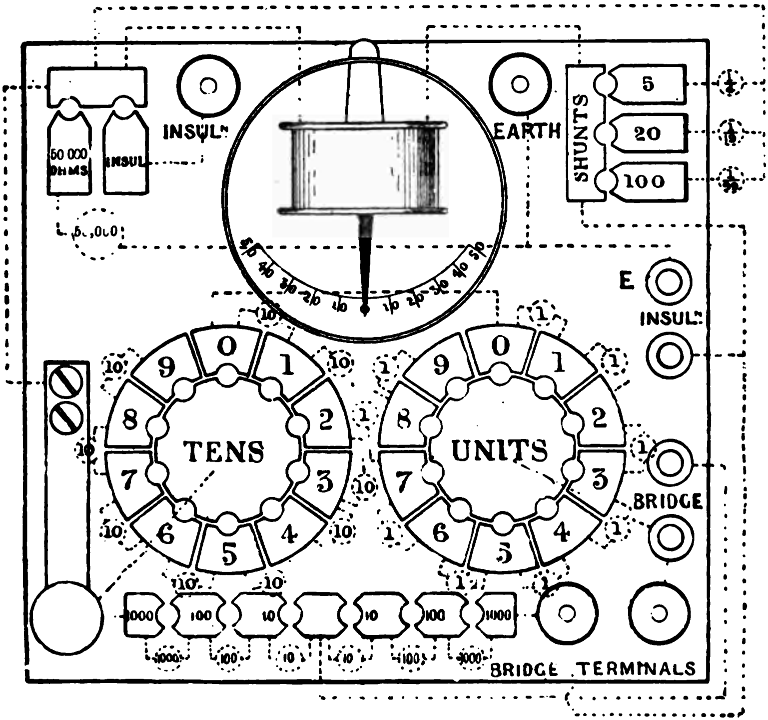
that one-tenth of the current only passes through these coils, and the readings on the dial must be divided by 10 to get the true resistance to earth. By this means the range of the readings in the in-

FIG. 1.—Silvertown testing set.

strument is much extended, and indications from 5,000 ohms to 10 megohms can be obtained.

These instruments are more extensively used for testing the wiring of buildings than any other kind of instrument. They are light and portable, and the generator affords a simple means of obtaining

a pressure as great or greater than that to which the installation will be subjected. This is very important, as defective insulation, which might with-



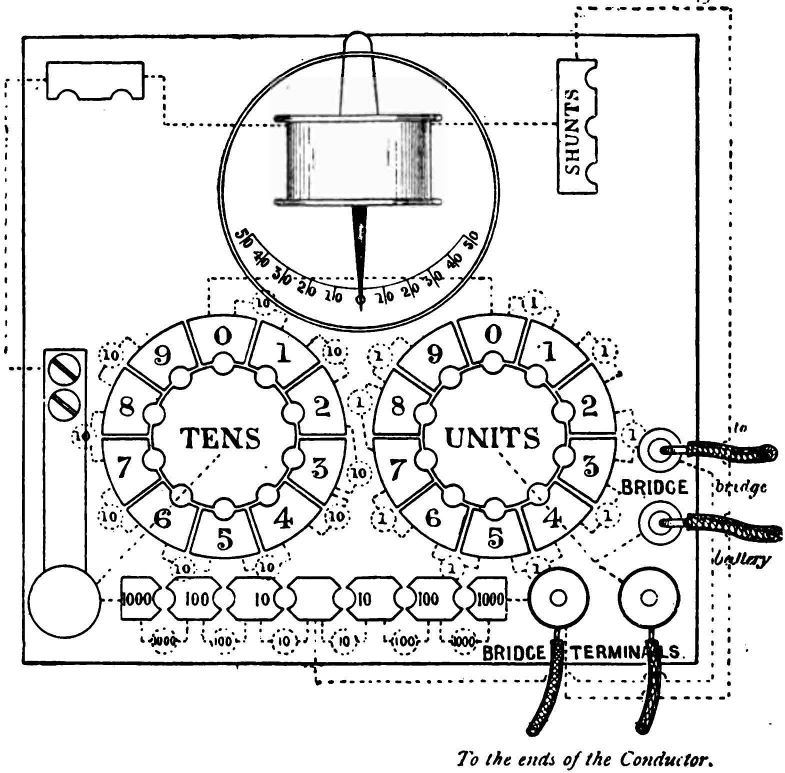
General arrangement showing all connections.
Fig. 2.

stand a pressure of a few volts, might not be able to resist a pressure of 100 volts or more.[1] In taking the

[1] These instruments are now made up to 500 volts, and sometimes even 1,000 volts.

tests the readings should not be taken until the handle has been turned for a minute or two.

Another instrument that is often used for testing



Connections for Testing Conductor Resistance.
FIG. 3.

purposes is known as the "Silvertown testing set," and is made by the India-rubber and Gutta-percha Company, Limited, of Silvertown. This set is shown

in the accompanying illustrations. Fig. 1 shows the outward appearance of the testing set, and Fig. 2 a general arrangement, with the connections marked in dotted lines. In order to obtain the necessary voltage for testing, a battery of 36 small Leclanché cells is employed, of which all or a few only can be used, according to circumstances and the nature of the tests to be taken.

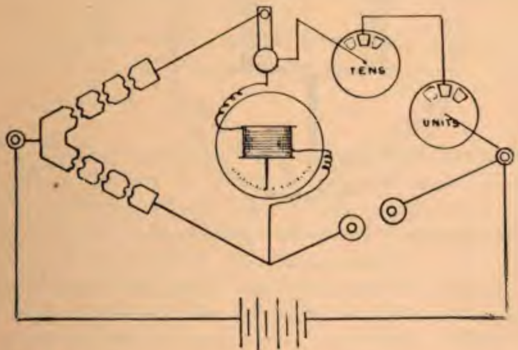
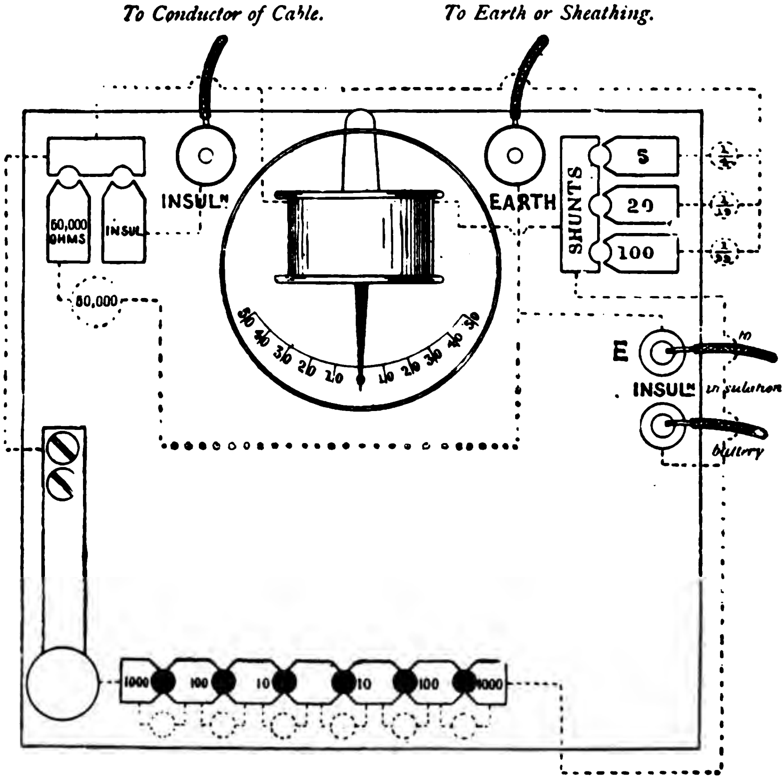


FIG. 3A.—Diagrammatic sketch showing Wheatstone bridge connections.

The instrument is divided into two parts, one of which is for testing the resistance of conductors according to the ordinary Wheatstone bridge method, and Fig. 3 shows this part of the instrument only, with the connections marked in dotted lines. In order to make this more clear a separate diagram is given in Fig. 3A, in which the four arms of the Wheatstone bridge are shown in the form usually given in text books. For testing insulation

resistances that part of the instrument shown in Fig. 4 is employed, the connections in this case also



Connections for Testing Insulation Resistance.
FIG. 4.

being marked with dotted lines. In order to take a test the current from the battery is first sent through a known resistance (50,000 ohms) and the de-

flection of the galvanometer needle noted. The current is then sent through the "line" to the earth terminal, and the deflection of the needle again noted. If this is the same as before the insulation resistance is 50,000 ohms, if greater the resistance is proportionately less, and if smaller the resistance is larger. It will be noted that the galvanometer can be "shunted," so that the readings obtained can be either 5, 10, or 100 times greater than if no shunt is used.

Certain instructions are issued with these instruments, explaining more fully their action. They are as follows :—

The battery consists of two parts: one—commonly called the bridge battery—is a set of three Leclanché cells of low resistance intended to be used in testing conductor resistances only, a purpose for which currents of electricity of sensible magnitude are required. The other part is a set of 36 small Leclanché cells having a total electro-motive force of 55 volts intended exclusively for measuring insulation resistances, or other resistances, of considerable magnitude. These cells are designed to give only very small currents of electricity. and care should be taken not to connect them inadvertently to the Wheatstone's bridge or otherwise put them on a circuit of low resistance. This battery, called the insulation battery, is subdivided into three sections of 3–15 and 39 cells, so that electromotive forces of about 5–25 or 60 volts can be employed as may be found convenient.

The only part of the instrument which requires detailed description is the galvanometer. This consists of a coil of fine wire on a brass bobbin, in the centre of which a small magnetic needle with an aluminium pointer is hung in the same way as is usual in compasses. The pointer projects through the opening in the end of the coil, and the excursions of the needle are limited by the size of the opening to about 45° on each side of

the centre. On removing the glass cover the needle on its point may be taken out by withdrawing the slide on which it is pivoted from inside the coil. The scale, which is a scale of equal currents, is approximately a scale of tangents, and is obtained empirically by calibrating the instrument. The north end of the magnetic needle points to the left-hand side of the box when it is swinging freely in its zero position.

On the left-hand side of the box is placed the controlling magnet, and the position of this affects the sensitiveness of the galvanometer. When the north pole of the controlling magnet is uppermost, the galvanometer will be most sensitive; on turning the magnet round, so that the south pole is uppermost, the deflection of the needle due to any given current will be reduced by about 40 per cent. Generally in testing the insulation of well-insulated wires, the galvanometer is required to be as sensitive as possible, and the north pole of the controlling magnet should be at the top; but for measuring conductor resistances, for which the galvanometer is generally amply sensitive, it will be found more convenient to bring the south pole uppermost, thereby causing the galvanometer needle to oscillate more rapidly.

Besides thus affecting the sensitiveness of the galvanometer, the magnet is also used to adjust the needle to the zero in its position of rest by turning it slightly in one direction or the other.

In preparing to test, the box should be placed on a table, or some other approximately level surface in front of the electrician, he facing the magnetic east, and the controlling magnet being in a vertical position. The pointer of the galvanometer will then be found to be swinging near its zero, and may be brought exactly to it by slightly turning the controlling magnet.

If at any time the galvanometer needle should become insensitive and sluggish, it may be due to one of several causes.

It may be that the needle has become demagnetized. This can be remedied by withdrawing and remagnetizing it with an ordinary horse-shoe magnet, care being taken that this is done in the same direction as before.

It may be that some dirt has found its way into the jewel.

This may be removed with a piece of soft wood cut to a fine point.

It may be that the jewel or the needle point is injured. In this case the slide should be removed and sent with the needle and pointer to the makers for repair. This will probably have occurred either through the whole instrument having received a blow when the lid is open and the jewel resting on the needle point, or through the brass spring in the lid of the box being bent so that it no longer presses on the lifter when the lid is closed, and the needle has consequently been resting on the point while the box has been carried about.

Testing Conductor Resistance.

The method used of measuring the resistance of the conductor of the circuit under examination is that of Wheatstone's bridge.

This method is so well known and understood that it is not necessary to give here any account of the theory, only to point out the arrangement of the different parts of the testing set used in this measurement, and to indicate what coils should be plugged in the bridge for testing different resistances to the best advantage.

Fig. 3 shows only those parts of the instrument which are employed in this test, and omits the parts and their connections which relate only to insulation testing. The parts employed are the following :—

1. The adjustable resistance. This, it will be seen, consists of two sets of 9 coils each connected to circular plug commutators or dials. One set of coils has nine resistances of ten ohms each, making ninety ohms in all ; the other has nine resistances of one ohm each, making nine ohms in all. If the hole marked with any number, say 5, is plugged in the ten-ohm dial, a resistance of fifty ohms is inserted between the connecting leads entering and leading away from the dial ; and a similar rule applies to the one-ohm dial. Hence if the hole 6 be plugged in the tens dial and the hole 8 be plugged in the units dial, a total resistance is inserted in the two in series of 68 ohms. The lowest resistance that can be obtained is given when both the 0 holes are plugged,

when the coil resistance inserted is zero. The highest resistance is obtained by plugging the two 9 holes, when the total resistance is 99 ohms. If no plug is inserted in one or both dials, the circuit is broken and the resistance is infinity.

2. The second part of the apparatus is the double set of proportional resistances, consisting of two coils of 10 ohms each, two of 100 ohms and two of 1,000 ohms, these constituting what is known as Wheatstone's bridge. Of these only one on each side of the centre is to be unplugged for any given test, and a rule is given later on for selecting the resistances to be employed to obtain the greatest possible sensitiveness; that is to say, for selecting those coils which will give the largest deflection on the galvanometer, when the resistance plugged in the dials varies by a given error from that of the circuit under test.

3. The third part is the galvanometer which has been already described. Its two terminals are connected to the two ends of the Wheatstone's bridge by depressing the contact key. It will be noticed that the shunt coils, with their plug commutator, are omitted from the diagram. This is done because they are not essential to the test, though they may be conveniently used when the balance of the bridge is not yet approximately correct, and very large deflections are being obtained.

4. The battery, as has been already described, consists of 3 Leclanché cells, having an electro-motive force of about 5 volts. One pole of the battery is connected in the usual way to the middle of the Wheatstone's bridge, and the other to the point where the end of the adjustable dial coils is connected to one of the terminals, to which the conductor under test is attached. The connections are made by inserting the plugs at the ends of the battery leads, in the two holes marked BRIDGE, and immediately this is done the current is established in the coils; the galvanometer circuit is of course not completed till the key is depressed.

5. The ends of the conductor to be tested are to be secured under the two terminals marked BRIDGE TERMINALS, and in measuring low resistances care must be taken that they are very securely attached.

The test is begun by selecting the coils to be unplugged in

the Wheatstone's bridge; to do this it is necessary to know approximately the value of the resistance to be measured. Generally some idea of its value can be formed, but if it is quite unknown, two coils on the bridge may be chosen at random and a preliminary measurement made. This measurement will enable the correct coils to be chosen for a further test.

The following pairs of coils are to be selected—

For resistances between 1 ohm and 10 ohms, left-hand coil, 100 ohms; right-hand coil, 10 ohms.

For resistances between 10 ohms and 100 ohms, left-hand coil, 100 ohms; right-hand coil, 100 ohms.

For resistances between 100 ohms and 1,000 ohms, left-hand coil, 100 ohms; right-hand coil, 1,000 ohms.

In all these cases coils will be employed in both dials, and a result giving two significant figures will be obtained; a third figure can always be found in measuring resistances between these limits, viz., between 1 ohm and 1,000 ohms, by observing the deflections of the galvanometer needles on both sides of the zero for different adjustments of the dial resistances near the balancing point.

For example we will suppose that the 10-ohm coil on the right-hand side of the bridge and the 100-ohm coil on the left-hand side are unplugged, and that when 45 ohms are plugged in the dials, and the key depressed, a throw of three divisions of the galvanometer needle is observed to the right; and when 46 ohms are plugged we get a throw of two divisions to the left on the galvanometer scale. It is clear that the resistance to be measured lies between 4·5 and 4·6, and is nearer to 4·6 than 4·5, as two is less than three; that is, the resistance is 4·56 ohms. As a further example, suppose 100 ohms to be unplugged on each side of the bridge, and 82 ohms to be plugged in the dials; on depressing the key, no deflection of the needle is observed. On plugging 81 ohms in the dials, a throw of six divisions to the right is obtained, and on plugging 83 ohms we get the same deflection to the left. We are then amply justified in putting the third figure in the result as 0, and the resistance to be measured is 82·0 ohms.

Resistances from ·1 ohm to 1 ohm may be measured either

with the same bridge coils as are used for resistances of 1–10 ohms, viz., 10 ohms on the right side and 100 ohms on the left, but only to two significant figures, since the tens dial will be plugged at 0.

Resistances of from ·1 ohm to 1 ohm may also be measured to three figures by using the bridge coils of 1,000 on the left side and 10 on the right, and resistances from 1,000 ohms to 10,000 ohms by using the bridge coils of 10 on the left and 1,000 on the right. For both these tests, however, more battery power is required than is provided in the ordinary portable battery supplied.

For making this test attention may be called to the following points, some of which have been noticed before.

Except in testing at the extreme range of the instrument, *i.e.* quantities less than 1 ohm or greater than 1,000 ohms, the galvanometer will be found amply sensitive, and it is better to place the south end of the controlling magnet uppermost, thereby reducing the time of the oscillations of the galvanometer needle.

The battery should be in circuit as short a time as possible to avoid running down the cells, and it is well to take out one of the battery lead plugs when any alterations are being made in the plug commutators, only replacing it just before pressing the galvanometer key.

Care should be taken to connect the conductor to be tested very securely to the bridge terminals. This may be done for very large or stranded conductors, either by soldering to their ends thin brass plates with holes in them of a suitable size to go under the heads of the terminals, or the connection may be made by means of finer wires soldered to the end of the main conductor. The resistance of these must be independently ascertained and subtracted from the gross result.

Measurement of Insulation Resistance.

This is a measurement of the electrical resistance of the insulating material of a cable to the passage of a current from the inside conductor through the insulation to the lead sheathing,

wet yarn, armour, or other outside conducting surface, and the inverse of the insulation resistance is the insulating conductivity, or, as is generally termed, the leakage.

This measurement is effected by a method known as that of direct deflections. It consists in passing a current from a battery through a galvanometer into a conductor of a cable whose farther end is free and disconnected, thence through the insulating material to the outside coating or earth, and so back along a temporary conductor to the other end of the battery, the deflection of the galvanometer needle produced by this current being noted. Replacing that part of the circuit which was formed by the insulating material of the cable by a standard resistance of known value, we obtain a new deflection of the galvanometer needle.

The quotient obtained by dividing the deflection produced by the current through the standard resistance by that through the cable insulation is a measure of the insulation in terms of the standard.

Thus, for example, suppose that a given battery produces on the needle of a galvanometer placed in series with the insulation of a cable in the manner described, a deflection of 10·3 divisions, and that on substituting a resistance of 1 megohm for the insulation we get 42 divisions, we find that the insulation resistance is $\frac{42}{10\cdot3}=4\cdot1$ megohms approximately.

Fig. 4 shows only those parts of the apparatus and their connections that are used in this measurement, those which relate only to the measurement of conductor resistances being omitted.

The arrangement, it will be seen, is as follows: One pole of the battery—the battery of 39 Leclanché cells giving an E.M.F. of about 60 volts is normally employed—is connected by a conductor, ending in an ebonite-headed plug, to the lower of the two plugged holes marked INSUL^{N}. Thence the current passes along a connecting wire to the block marked SHUNTS, and thence through the galvanometer to the upper block on the other side; we may observe in passing that these two main blocks, one on each side, are practically the terminals of the galvanometer. If a shunt is plugged, $\frac{1}{5}$th, $\frac{1}{20}$th, or $\frac{1}{100}$th only of the

current passes through the galvanometer, the remainder finding its way through the corresponding shunt coil.

From the upper block on the left-hand side, the current may take two paths, according as the hole marked INSUL$^{N.}$, or that marked 50,000 ohms, is plugged; if neither is plugged, the circuit is broken, and no current can pass. This plug forms consequently a convenient make and break key If the hole marked INSUL$^{N.}$ is plugged, the current passes to the terminal marked INSUL$^{N.}$, so through the insulating covering of the cable to the outside sheathing or earth, back to the terminal marked EARTH and the plug-hole marked E, and then along the lead to the other pole of the battery. If, however, the hole marked 50,000 ohms be plugged, the current will pass through the coil of 50,000 ohms, then along a connecting wire to the plug-hole E, and so back to the battery.

In beginning this test the conductor of the cable, or insulated wire, or a temporary lead attached to it, is connected to the terminal of the instrument marked INSUL$^{N.}$, and another lead, connected to the outside sheathing of the cable, or the wet soil in which it lies, is attached to the terminal marked EARTH, care being taken that these leads are separated, and that no circuit exists between them except through the insulation of the cable.

The test then consists in—

1. Noting the deflection obtained when the 50,000-ohm hole is plugged—*i.e.* obtaining the deflection produced by the current passing through a known resistance; this is called taking the constant of a galvanometer. It will be found in practice that with a battery of 39 cells supplied, it is necessary to use the shunt, giving a multiplying power of 20; and we may note here that the passage of the current through a galvanometer shunted thus, and then through 50,000 ohms, gives the same deflection as passing the whole current through the galvanometer not shunted and through a constant of 1,000,000 ohms. In short the deflection thus obtained is the deflection given by the battery through one megohm.

2. Transferring the plug to the hole marked INSUL$^{N.}$, and again noting the deflection obtained, the galvanometer being shunted if necessary to give a convenient reading.

On dividing the deflection on the scale obtained when taking the constant by the deflection obtained in the second part of the test, and multiplying the deflections by the shunt or shunts employed, we obtain the insulation resistance of the cable in megohms.

For example: suppose that the current from the battery when passed through a constant resistance of 50,000 ohms gave a deflection of 42 divisions on a galvanometer shunted to $\frac{1}{20}$, and that when passed through the cable insulation it gave 23 divisions with the galvanometer shunted to $\frac{1}{5}$, the insulation resistance would be $\frac{42}{23 \times 5}$ megohms = ·37 megohm approximately.

For another example: if having found the same galvanometer constant, we obtained from the cable insulation a deflection of 10 divisions with no shunt employed, the insulation resistance of the cable would be $\frac{42}{10}$ megohms = 4·20 megohms.

It will be observed that, when al the holes in the straight commutator near the front of the blox are plugged, the key on the left-hand side, which is used in the bridge test as a galvanometer make and break key, becomes for the insulation test a short circuit key, and is useful for checking quickly the oscillations of the needle.

(N.B.—Although the maximum voltage of the testing battery usually employed with this Testing Set is only 60 volts, the set can be used with a testing voltage of 200 volts, as required by the Board of Trade regulations. In this case, instead of using the multiplying power of 20 as described above, the multiplying power of 100 should be used in taking the constant—the deflection thus obtained will be the same as that which would be given by the unshunted galvanometer through a total resistance of 5 megohms, and the calculation of the resistance to be measured would then be made in exactly the same manner as described above, except that 5 megohms will be substituted for 1 megohm.)

In making this test the following points may be called attention to:—

1. Too much care cannot be taken in preparing the ends of the cable. Since we are measuring a very small current of electricity passing from the conductor to the outside sheathing, through the insulated covering, it is clear that our results will be

entirely misleading if any current be allowed to pass over a dirty surface at the ends where the conductor is exposed. These ends should be looked to before testing, and in the case of india-rubber or other firm material, the section of the insulator should be pared all over with a sharp and perfectly clean knife.

2. Care should be taken not to short circuit the battery, which may easily occur in two ways. One is by allowing the two battery plugs to touch one another, when the other ends of the leads are attached to the battery terminals; and another is by allowing the lead attached to the earth terminal to touch that attached to the insulation terminal.

In both cases the battery of small cells will be for a time much overworked, and in the second the needle may become bent or demagnetized.

3. Another point that may be noticed is that in deducing the insulation resistance per statute mile from a test on any given length, the result obtained from a test on the latter is to be multiplied by the length of the piece in miles, and not divided by it.

For example, if the insulation of a cable three miles long be 15 megohms, the insulation per mile will be $15 + 3$ or 45 megohms; or again, if the insulation of a piece of cable, whose length is 350 yards, be 7,520 megohms, the insulation per statute mile will be $\frac{7520 \times 350}{1760}$ megohms = 1,495 megohms.

CHAPTER VIII

Costs and Estimates for Wiring

TO treat the subject of the costs of wiring under the various systems in an adequate manner would be impossible within the scope of this treatise, and it is only possible to give a few hints that may serve as a guide to those who are installing the electric light. The conditions are so varied in different buildings that, unless the details of a scheme of wiring are properly considered, it is quite impossible to say what the costs may be. One hears frequently of contractors who undertake to do the wiring of a building at so much per light (very frequently an extremely low price); but this is a very indefinite method of estimating, unless it is specified exactly what is included—it is in this respect that the public are often deceived, with the result that large sums of money have to be expended in unexpected "extras." As regards wiring only, the term of "cost per light" is misleading, since a large number of lights may be grouped together in one fitting, in which case the wiring is the same as that for one light, except as re-

gards the size of conductor employed; hence it is preferable to calculate the number of "points" of light in a building. Again, it should be specified if fittings of any kind are included in the costs, as tenders are sometimes sent in, in which it is assumed the fittings will all be "extra." Other points in tenders, such as cutting away and making good, moving of furniture, taking up of floor boards, fixing of expensive fittings, should all be carefully considered, as the cost of these items forms a considerable percentage of the costs of the whole installations. When obtaining prices for wiring work from contractors, great care should be taken in giving out the work to see that everything that can possibly be included is allowed for in the price. Some points that are likely to be omitted in a contractor's specifications are:—

(1) Cutting away and making good, painting and varnishing decorating work.

(2) Taking up carpets, removing furniture, etc.

(3) Cost of fixing fittings.

(4) The supply of lamp-holders, lamps, and shades.

(5) Removal of gas-fittings and stopping off the supply.

In the catalogues of manufacturers of fittings it is a usual practice to exclude the cost of holders, lamps, and shades, although they appear in the designs. It is far best for any one who is ignorant of the intricacies of electric lighting to employ a consulting engineer to draft a complete specification and submit it to several good contractors; the successful one will then be obliged to follow the

specification, and any extras have to be allowed by the consulting engineer.

When one is told that installations are put up at prices of 10*s*. per point, including fittings, etc., complete, it is quite certain either that the contractor is foolishly losing money, or else that very inferior materials and labour are being employed.

In any ordinary building the materials for wiring can be calculated fairly exactly, the labour costs being the most difficult to estimate. In a West-end London house the costs of materials, in a wood-casing system, may roughly be taken as follows :—

		£	*s.*	*d.*		
Cables . . .	about	0	4	0	per	point.
Casing . . .	,,	0	1	6	,,	,,
Switches . . .	,,	0	1	0	,,	,,
Fuse-boards, main Switches, and Sundries . .	,,	0	2	6	,,	,,
Labour . . .	,,	0	10	0	,,	,,
Lamps . . .	,,	0	1	0	,,	,,
		£1	0	0		

The labour, it is safe to say, is *never* less than 5*s*. per point, and may be as much as £1 per point, if the difficulties are great and expensive fittings have to be fixed. It will be seen that the above prices are based on *actual cost prices to the contractor*, no account being taken of fittings. Even if the plainest fittings are employed, the cost will be, say, 3*s*. each

in addition; it therefore becomes quite apparent that electric lighting cannot be done at anything like 10*s*. per point, including fittings, and the public cannot be too careful in discriminating between good and bad work.

Competition is responsible for a great many inferior installations, and if prices are unduly cut down, bad work in some form is likely to be put in. The above approximate prices are the nett prices actually paid by the contractor for wages and materials, taking no account whatever of profit or allowances for contingencies or superintendence, and if these are to be taken into consideration, an increase of something between 30 and 50 per cent. over the whole nett costs should be allowed. Assuming, therefore, that the labour per point is about 10*s*. (a very moderate inclusive estimate in most cases), it follows that for good work, inclusive of everything, and assuming that simple fittings only are employed, a price of 30*s*. per point is not at all an extravagant price to pay for wiring. The prices above given must not be taken by any means as universally applicable, but they do apply in the case of a large number of ordinary dwelling-houses where the conditions are not especially difficult. In country house installations the costs would probably be greater than these, owing to the fact that wiremen and carpenters receive "out-money" allowances. For the same class of buildings the cost of concentric wiring would be about the same, but for iron barrel system the costs are greater, as the tubes are more expensive than casing, and the

labour cannot well be less. For similar installations the cost per point wired should be from 10*s*. to 15*s*. more expensive than with wood casing. It is impossible to give even the approximate costs of wiring works, factories, or theatres, or, indeed, special buildings of any kind ; each installation must be judged on its own merits, and it must be borne in mind that the cost of the labour determines more than anything else the total cost of the whole installation.

In drawing up specifications for wiring, a schedule of the number of lamps, points of light, switches and fittings is made, and the exact positions indicated. When this is arranged, the sizes of conductors and number of fuse-boards can be calculated. The exact conditions under which the contracts are to be carried out must be clearly specified. In order to give the reader a general idea of the usual character of a good specification for the wiring of an ordinary dwelling-house in London, of about, say, 75 lights, as carried out under a consulting engineer, the following may be taken as an example for a wood-casing installation :—

Specification for Complete Installation, including Wiring and Fixing Fittings, for 75 Lights.

General.—The whole of the work to be carried out in accordance with the specification to the satisfaction of the consulting engineer, in accordance with the requirements of the supply company and fire insurance companies interested.

The contractors to make good all defects that

may appear within twelve months from the date of completion of the contract, such defects being due to faulty material or workmanship only.

Payment.—Payment for the work to be as follows :—

80 per cent. on the certificate of the consulting engineer.

10 per cent. on the satisfactory completion.

10 ,, ,, one month after completion.

Cables.—All cables to be insulated with pure and vulcanized rubber, then taped and braided and covered with preservative compound. The insulation resistance to be at least 600 megohms per mile, at 60° Fahr., after 24 hours' immersion in water, the electromotive force used for testing being at least 200 volts.

All the conductors to be stranded and tinned, the conductivity of the copper in no case being less than that of pure copper according to Mathieson's standard ; conductors of opposite polarity to be coloured red and black, and all single-pole switches to be fixed on the red conductor.

Current Density.—The ampère density of the leads must not exceed 800 ampères per square inch, assuming that every lamp is of 16 c.p. and requires 100 volts.

Casing.—The cables to be run in best American whitewood casing throughout, except behind plaster, and when passing through walls and partitions, in which cases metal tubes must be employed, consisting of composition or brass tubing or iron barrel. Wherever exposed to view the casing is to have

two coats of paint (to suit the decorations), and in damp situations to be shellaced inside and out.

Bunching of Cables.—Conductors of similar polarity may be placed in the same grooves of casing, but ample room must be allowed in the grooves for drawing in and out.

Distribution Boards and Main Leads.—One main double-pole switch and fuse for 50 ampères to be fixed close to the position selected for the entrance of the mains, and a pair of 19/16 to be run without any diminution in area, to at least two subdistribution boards placed in convenient positions, preferably at the back of staircase. From these boards 5 ampère circuits to be run to the various lamps throughout the house.

The main-pole switch and fuses to be mounted on two enamelled slates, separated by a wood fillet. Each switch to have a quick double break of at least three inches, and the current density in the metal must not exceed 250 ampères per square inch. The slates to be mounted on hardwood battens, and to be well packed out from the wall. The whole to be enclosed in a polished teak case, with glazed front and lock and key.

In the distribution boards each pole is to be separately mounted on enamelled slate, with a dividing strip of polished hardwood between the mains at least 1½ inches wide. Two omnibus bars to be provided, from which 5 ampère circuits are to be taken to the various lamps throughout the house, the current passing through easily replaceable fuses, each guaranteed to melt with a current

of 10 ampères; the terminals of the fuses to be at least 1½ inches apart. All connections to the 5 ampère circuits to be made on the surface of the boards. Each subdistribution board to be enclosed in a polished teak box with glazed front.

In order to secure perfect insulation it is preferable to bush the holes for the screws, holding the slates to the wood battens with ebonite, both in the main switch distribution boards, so that the metal of the screws cannot come in contact with the slates.

Joints.—To be carefully made in the most approved manner and soldered with resin, at least three layers of rubber strip being put in next the conductor, and this insulation protected by a covering of two layers of strong waterproof tape.

In order to avoid joints as far as possible, the conductors should be left long enough to reach the holder of the fitting employed, wherever this can be so arranged.

No joints are to be made where the conductors are embedded behind plaster.

Switches, Wall Sockets, and Ceiling Roses.—These to be of the latest design, and fixed on polished blocks of teak or hardwood, recessed at the back to allow space for the conductors and casing to be brought to the terminals. Where necessary rough wooden blocks must be provided, as fixing for the polished wood blocks.

Cutting away and Fixing Fittings.—The tender to include all cutting away and making good, and also the cost of fixing and wiring any fittings that

may be selected. It is understood that substantial wood blocks must be provided and fixed to support the weight of the heavier fittings. Where floor boards are taken up they are to be refixed with screws, so that access can be gained to the cables if necessary.

Lamp-holders, etc.—Seventy-five lamps and holders to be provided, and also the cost of ten spare lamps. The holders to be of the Edison & Swan bayonet description, and of the latest design.

Alterations and Additions.—No alteration or addition to be made without consent in writing of the consulting engineer. Any dispute that may arise during the execution of the contract shall be settled by the consulting engineer, whose decision shall be final.

Tests.—On the completion of the work, including the fixing of all fittings, the installation must be tested with a pressure of at least 200 volts, and the insulation resistance to earth of both mains together shall not be less than 3 megohms, and the insulation between mains not less than 1 megohm.

The above, with the addition of a schedule of lights and switches and their position, may be taken as a fair example of the specifications now in vogue for lighting. It will be observed that the contractor has to work under severe conditions, and if the installation is properly carried out it is worth at least from 25*s.* to 30*s.* per point, excluding the cost of fittings only, but including lamp-holders.

Similar specifications are issued on much the same lines for iron barrel installations. The kind

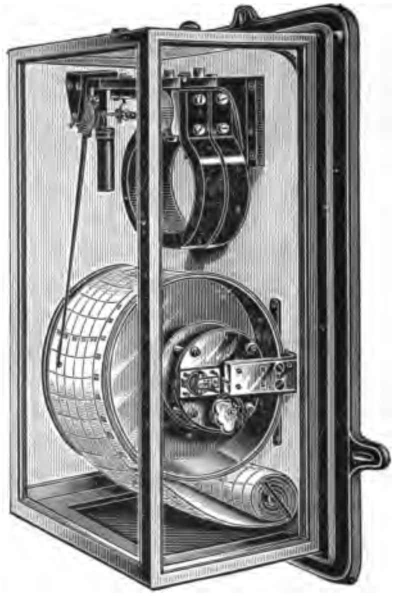
of barrel to be employed must be carefully specified, and also the various details of the junction boxes and bends. Iron barrel "elbows" should not be allowed, as it is very difficult to draw the wires in through them.

CHAPTER IX

Electricity Meters and Systems of Charging for Electric Current

IF it could be conveniently arranged to keep the electric pressure in houses under control by means of taps, as is done with gas, and thus minimize the evil arising from variations of pressure in the supply mains, and if too some cheap and reliable system of storing electrical energy on a large scale could be devised, there would then be no difficulty in charging consumers in an equitable manner for electric current supplied by central stations, and there would be no need for the somewhat elaborate systems of rebates according to " maximum demand " now in vogue. Unfortunately, however, the light given by incandescent lamps varies enormously with slight variation of pressure, since if the pressure is too low for the lamps the consumer pays for current that is useless to him, as he gets no light, and if it is too high an abnormal brilliance of the lamps is followed usually by the breakage of a large number of filaments in the lamps. In both cases, however, the consumer pays for the current consumed, and is liable to suffer. In order to protect

the public the Board of Trade has therefore laid it down in their regulations that the variations in pressure from the normal must not be more than 2½% either above or below, making a total variation of 5%. Thus, if the normal voltage of supply is,



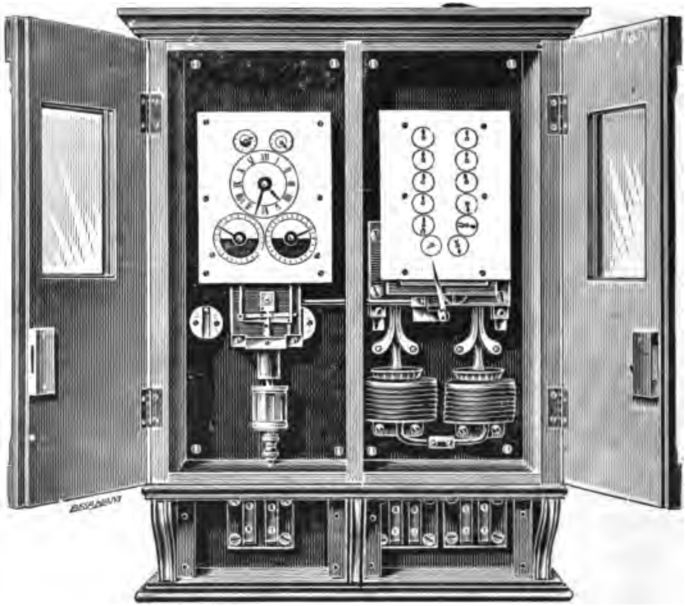
Recording voltmeter.

say, 200 volts, the pressure should not rise higher than 205 or fall lower than 195 volts. If therefore a consumer can prove that for given periods the variations in pressure at the house terminals have exceeded the above limits, he can dispute the accounts

for the periods in question. A useful instrument to instal therefore is a recording voltmeter as shown in the illustration. In this instrument the pressure is recorded automatically on a strip of paper, which is moved forward by clockwork, and the instrument resembles in its general appearance and action the common self-recording barometer. Meters will register current if it is supplied at the correct pressure or otherwise; the above regulation of the Board of Trade is therefore very necessary in order to protect the public. Meters are usually made to register in Board of Trade units, that is to say, they register kilowatt hours; thus, if the pressure of supply is, say, 200 volts, 5 ampères passing for one hour would register one unit, or 10 ampères for one hour at 100 volts would similarly register one unit.

Owing to the fact that it is too costly to store electrical energy on a large scale for central station purposes it is found in practice to be necessary to instal machinery of such an output that it is capable of dealing with the maximum lighting load which may be required, and this load is heaviest in the evenings between six and eight o'clock. A great part of this machinery is lying idle and unremunerative during daylight hours, as there is only a comparatively small demand in the daytime for electric light; it is the object therefore of central station engineers to try to induce their customers to use current during the day (in order to prevent the machinery lying idle) and diminish their consumption in the evening during the hours of maximum

demand, *i.e.* between six and eight o'clock, in order to avoid capital expenditure on machinery. They try to effect this object by making arrangements to charge their consumers at a lower rate for energy consumed during the day and at a higher rate for



Time switch with two-dial meter.

energy consumed during the evening. This can be done in several ways, as follows :—

(1) A meter can be provided with two sets of dials, one for the day and one for the evening load, and either of these sets can be put into operation by

means of a time switch operated by a clock. The day current is then charged for at a lower rate than the current consumed during the evening. One of these time switch instruments is shown in the figure in conjunction with a two-dial Aron meter.

(2) One set of dials can be used, and the time switch can be used to insert a resistance in the shunt circuit during the daytime, so that the meter registers only a fixed proportion on the total units flowing through it during the day. The charge is made out according to the reading on the dials, although a greater number of units has passed through the meter than is actually registered. In the case of meters without shunt circuits this cannot be done.

(3) No time switch is used, but an instrument called a "maximum demand" indicator is fixed, which shows the maximum amount of current that passes through the meter at any given time. It is then assumed by the supply company that this maximum amount of current has passed through the meter for a given number of hours every quarter, usually one hour per day for 90 days, and the number of units so reckoned is deducted from the total number of units consumed during the period and charged for at a higher rate; the remaining units are charged for at the lower rate. An example may perhaps make this clearer. Suppose that the total number of units consumed during the quarter amounts to 200 at 100 volts pressure, and that the maximum demand as shown by the indicator is 15 ampères—it is assumed then that 15 ampères has passed for 90 hours during the quarter,

and that $\frac{15 \times 90 \times 100}{1,000} = 135$ units have been consumed at this rate. If now the higher rate of charge is 7*d.* per unit, and the lower rate 2*d.*, 135 units will be charged at 7*d.*, and 200–135=65 will be charged at 2*d.*

This method of charging is extremely convenient, and effects its object perfectly ; it tends to prevent

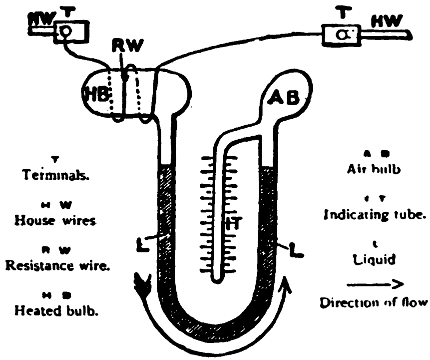


Fig. 1.—Sketch of Wright's maximum demand indicator.

consumers using a large number of lamps at one time, and encourages a demand for current during the daytime. It is largely used, and is known as the maximum demand system. Two illustrations are given here of Wright's maximum demand indicators. It consists essentially of a V-shaped (Fig. 1) tube with a bulb at each end, and it contains a coloured liquid. At the end of one limb there is a smaller tube, called the indicating tube. On the

outside of the bulb *H B* is a copper coil through which the main current passes. When the instrument is working the current heats the air inside this bulb and causes the liquid to rise in the other limb. The amount of rise (and therefore the current) is registered by the falling of the liquid into the indicating tube, and the maximum current in ampères that has gone through at any given time is thus registered. It may be noted that a short circuit has no effect on the instrument, as there would not be sufficient time for the air to be warmed before the fuse melted. Usually the instrument is read every quarter; the instrument is then re-set by turning it upside down—this empties the tube that registers the number of ampères, and leaves everything ready for a new reading for the next quarter. Fig. 2 shows the general appearance of the indicator.

The above methods of charging for current may appear somewhat arbitrary at first sight, but in reality they are not so; it is certainly advisable and right that some sort of sliding scale system for payment as sketched in the above arrangement should be adopted.

It is impossible to describe in detail all the electricity meters as made to-day—their name is legion and many of them are extremely complicated—all that can be done therefore is to describe briefly one or two meters of the better known types.

Meters may be either integrating watt meters or merely ampère hour meters, but in both cases their readings are taken as registering Board of Trade units; in the case of ampère hour meters, however,

it is assumed that the volts remain constant. As a

FIG. 2.—Wright's maximum demand indicator.

matter of fact the volts do *not* remain constant, but

the customer pays just as though there were no variation. With integrating watt meters if the pressure rises the increase of volts is registered on the dials, and the consumer pays both for the increase in units and also for the lamps that are destroyed owing to the increase of pressure. It is well therefore that the Board of Trade has issued the abovementioned regulations regarding the variations of pressure at which electric current is to be supplied from central stations. Meters that have no shunt circuits are ampère hour meters; of this class the Ferranti and Chamberlain-Hookham direct current meters are good examples. Of integrating watt meters the Aron and British-Westinghouse meters are good examples.

Some meters are driven by clockwork, like the Aron & Mordey-Fricker meters; others again are known as electric motor meters, and of these the Ferranti and British-Westinghouse & Thompson may be taken as examples. For registering small currents the Bastian electrolytic meters are largely used, as they are cheap to manufacture. They are made on an entirely different principle; the current passes through an electrolytic cell consisting of slightly acidulated water, and liberates oxygen and hydrogen in exact proportion to the current traversing the cell. This meter will be described later. It can only be used with direct currents.

Some meters, like the Aron & Mordey-Fricker, can be used for both alternating and direct currents.

One of the principal difficulties in the manufacture of meters is to make certain that they read correctly

with very small currents passing through them. If, for instance, the total range of a meter is up to 50 ampères at 200 volts, it is extremely doubtful if it will register correctly the current consumed by a lamp of 8 c.p. On the other hand, a meter with a range of only 10 ampères would be much more likely to register correct the currents from one lamp. It is advisable therefore when applying for a meter to instal one with as low a maximum current as is consistent with safety in order to secure correct registration at low readings. This point is frequently overlooked, and it often happens that when houses are left in charge of a caretaker and only a small amount of current is consumed the meters register incorrectly at the low readings, and trouble arises.

Aron Meter.—This meter has reached a high state of perfection after many years of development, and from a theoretical point of view is perfect. It has a wide range, and will register the smallest currents, but it has a very large number of parts, which means necessarily that it is more liable to get out of order than a meter with fewer parts. By referring to Fig. 1 it will be seen that there are two pendulums, each of which is worked by a separate clock, and both these clocks are electrically wound up every ten minutes or so by an exceedingly ingenious winding arrangement worked by the shunt current. The energy from the spring is transmitted to both clocks by means of a differential gear, so that if one clock tends to stop the other can go on.

At the end of each pendulum there is a shunt

coil, and as long as the pressure remains constant the current in these coils remains constant. The coils at the bottom of the instrument are called the main coils, as they carry the total current

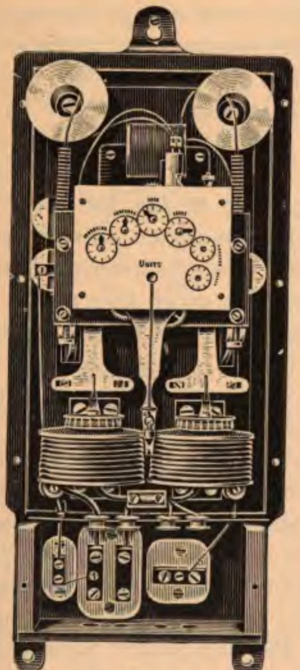


Fig. 1.—Aron Meter.

through the meter. These two coils are wound in opposition to one another. The action of the meter is as follows: When a current flows through the main coils one of the pendulum coils is attracted

and makes the clock attached to it go faster, and the other coil is repelled, making its clock in this case go slower. The variation in pace of the two clocks is transmitted to the dials through a second differential gear. The meter is so calibrated that the dials register the current and pressure in units (the pressure is registered because increase or diminution of current in the pendulum coils acts on the pace of the clocks in a similar manner to alteration of the current in the main coils). From the foregoing it will be obvious that when there is no current passing through the mains the two clocks should go at exactly the same pace, or synchronously, as it is termed. Now this synchronism is difficult of attainment in practice, so in this meter an extremely beautiful arrangement has been introduced to obviate the necessity of having absolute synchronism. This works as follows: Assuming one clock to go faster than the other, the error thus introduced would be obviated if the pendulums could be periodically interchanged, as the slow clock would then travel faster and the fast clock slower; now in practice it is of course impossible to shift the pendulums, but to all intents and purposes it can be done electrically by reversing the current in the shunt coils on the pendulums periodically. This is done by a switch worked by the clockwork, and at the same time an additional wheel in connection with the mechanism working the dials is thrown into gear, thus causing the dial hands to turn always in the same direction in spite of the reversal of current in the shunt coils. In order to be appreci-

ated, the mechanism of this meter should be thoroughly examined. The differential, winding, and synchronizing gears are each perfect in their way, and are worthy of careful study. The instrument can be calibrated to some extent by altering the

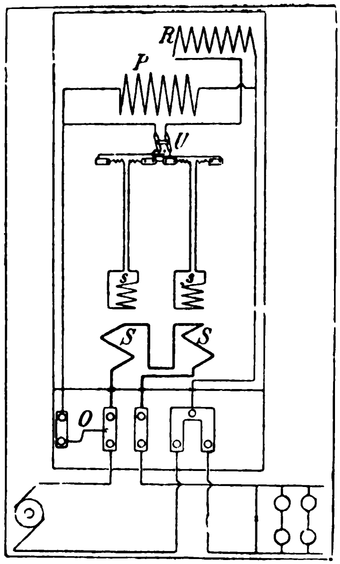


FIG. 2.—Diagrammatic sketch of connections in Aron Meter.

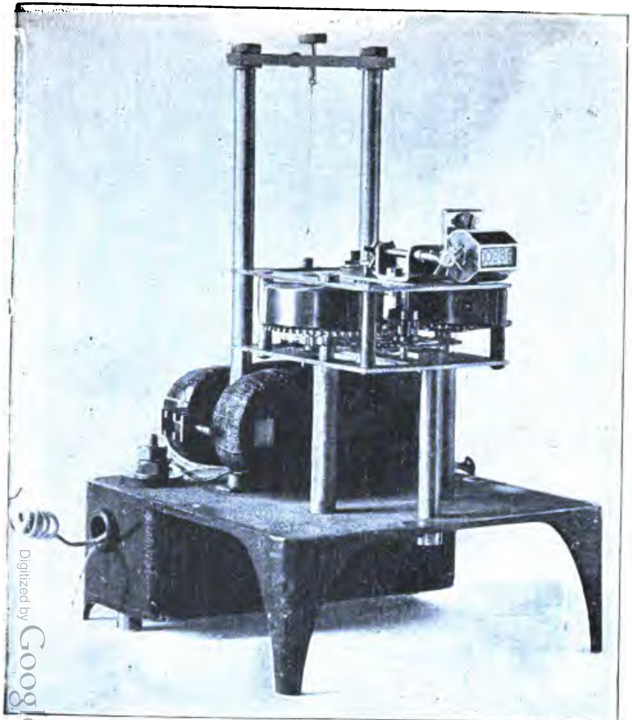
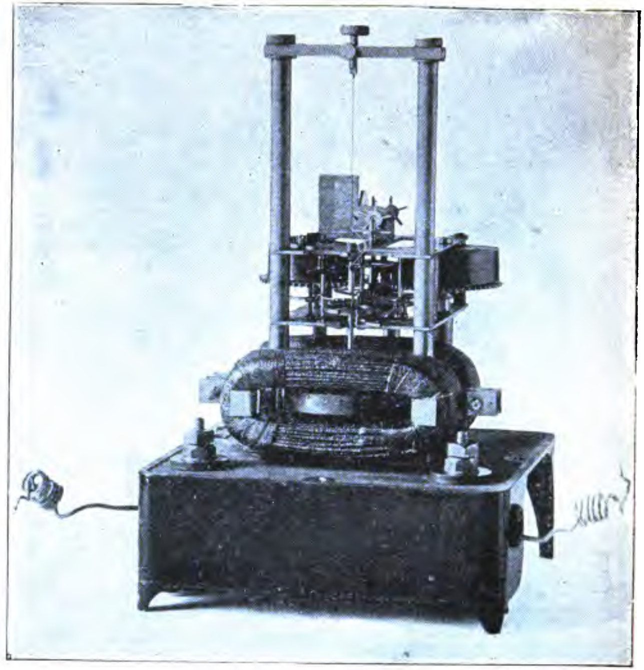
relative position of the pendulum and main coils or by altering the resistance in series with the pendulum coils.

If used as an alternating current meter it is necessary to make trifling alteration in the electro magnet working the winding gear.

Fig. 2 shows diagrammatically the electrical connections. *U* is the reversing switch for the pendulum coils, and *R* a resistance in series with these coils. *P* is the coil for the self-winding arrangement, and the main current passes through the coils *SS*.

Mordey & Fricker Meter.—This ingenious meter is also a clock meter, and is hand wound. Except for the clockwork, it has very few parts, and it is designed especially as a cheap meter for small currents. Its range is not great, but it will record very small currents, and can be used either for alternating or direct currents. It has no shunt current, and is therefore an ampère hour meter. The clockwork is that of an ordinary spring balance-wheel clock, but the hair-spring and balance-wheel are replaced by a magnetizing coil conveying the main current, and a wheel with a number of soft iron needles laid parallel to one another and embedded in slate. The arrangement of the needles is similar to that of the magnets on the ordinary marine compass card.

On referring to the figures it will be seen that the balance-wheel with the needles embedded in it is made to vibrate inside the current coils, and these coils act like the hair-spring of the balance-wheel, the pull they exert being exactly proportional to the current passing through the coils; the result of this is therefore that for small currents the clock goes very slowly, and consequently the balance-wheel with the needles vibrates slowly from side to side, and as the current increases the clock goes faster and faster and the balance-wheel vibrations are proportional to the current. The range of the

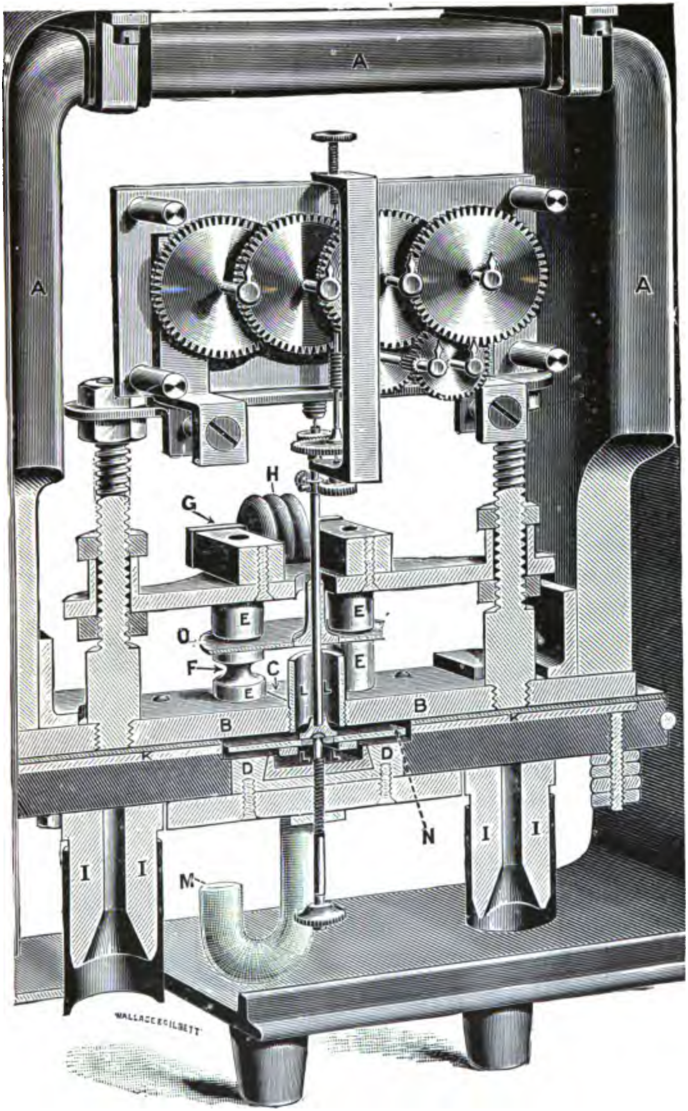



Mordey Fricker Meter.

meter is small because difficulties arise when the comparatively speaking large balance-wheel is made to move backwards and forwards very quickly. This meter reads direct in units, and the dials record the number of vibrations of the balance-wheel. As the balance-wheel is heavy, it is suspended by means of a torsionless thread from the top of the instrument as shown in the diagram. As the accuracy of this meter depends on the amplitude of the vibrations being equal at all loads, a very ingenious arrangement has been introduced by which the balance-wheel is made to do work against friction towards the end of each vibration by setting in motion a small V-shaped piece of metal, which oscillates to and fro at each vibration until the amplitude is reduced to the normal.

When the current is passing through the meter the clock ceases to work entirely, and therefore the mainspring does not run down. It is found in practice that an eight-day clockwork is sufficient to work the meter for a full quarter.

Chamberlain & Hookham Meter.—This meter is one of the best known and most reliable meters. The direct current instrument is an ampère hour meter which has, comparatively speaking, few parts. It is an electric motor meter, the magnetic field traversing the armature being produced by a permanent magnet, *A*. (See Figure, which shows a back view of the meter.) The lines of force from this magnet travel along *BB*, and then divide into two directions, part travelling upwards through the iron pillars *EE* and the brake disc *O*, and completing the magnetic



Chamberlain and Hookham Meter. Back view.

circuit through the iron bridge piece *G*. The other part, travelling downwards through the mercury bath *L L*, containing the copper armature disc *N*, completes the magnetic circuit through the iron bridge piece *DD*.

The main current is made to pass through the armature disc *N* by means of the copper strips *KK*, which are connected to the terminals *II*.

The mercury bath *L L* is in connection with the ends of the copper strips *KK*, so that there is a circuit of very low resistance between the two terminals *II*. The armature *N* revolves because the current and lines of force mutually react on one another, producing a torque. The torque thus produced is directly proportional to the current, provided the magnetic field remains constant; therefore the revolutions of the armature are also directly proportional to the current, and the dials are connected to the armature spindle in such a way that the current consumed is recorded in units.

The brake disc *O* on the same spindle as the armature is inserted in the magnetic circuit to prevent the meter going fast; it is, in fact, merely a brake which acts with a force nearly constant whatever the current may be passing through the meter. It causes the motor to do a small amount of work, and increases the range of the meter to a very large extent.

The friction on the pivots of the armature spindle is reduced to a minimum, as the weight of this part of the mechanism, including the brake disc, is carried by the mercury bath.

In order to compensate for the fluid friction of the mercury travelling round in the bath, a small coil, *H*, of a few turns only is introduced into the main circuit, and this has the effect of weakening the magnetism through the brake disc, and thus allows the meter to go a little faster to compensate for the loss of speed due to the fluid friction.

These meters are all sent out with a testing coefficient label by which a meter can be tested for accuracy at any time when in position. The calibration of the meter is so arranged that the current in ampères passing through the meter multiplied by the time in seconds (or fraction of a second) taken for one revolution of the armature disc is equal to the testing constant. Thus, for instance, if the testing constant is, say, 17, and the current passing through is 10 ampères, one revolution of the armature will be completed in 1·7 second. It is generally convenient for purposes of accuracy to take the time of several revolutions, say 20, in which case

$$\frac{\text{current} \times \text{time of 20 revolutions}}{20} = \text{testing constant.}$$

By thus taking the time of a given number of revolutions of the disc at any given current, the working of the meter may be efficiently and quickly checked without reference to the dials.

When installing the meter the mercury bath is filled through a tube fixed to the bath, and before the meter will work the indiarubber pad pressing against the brake wheel must be released by turning the screw which keeps it in position (this rubber pad and screw is not shown in the drawing).

Westinghouse Alternating Current Integrating Watt-Meter.—Three figures are given here of this interest-

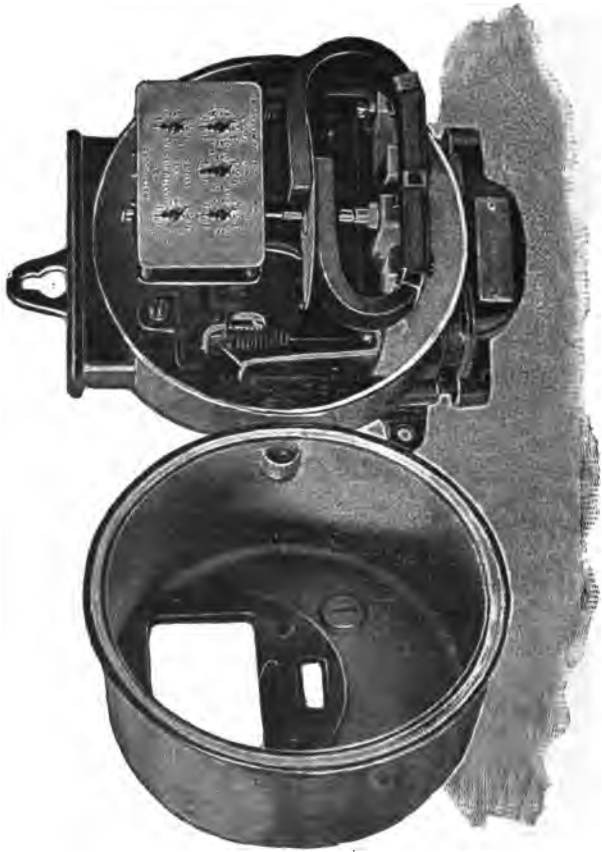


FIG. 1.—Westinghouse meter, general view.

ing meter. Figures 1 and 2 give general views of the instrument, Fig. 3 a diagrammatic sketch of the

magnetic and electric circuits. It is a motor meter

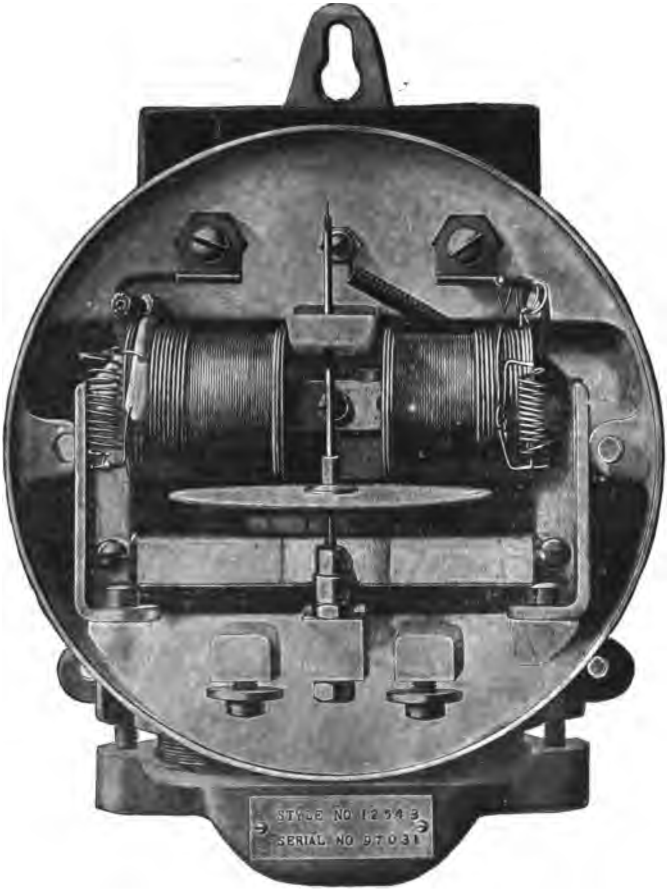


FIG. 2.—Westinghouse meter with dials and brake magnet removed.

and the student should study the theory of single

phase induction motors in order to grasp the theory of this meter. The armature consists of light metal disc revolving between three alternating magnetic poles (see Fig. 3). The current in the fine wire coils is caused to be out of phase with the current in the main coils by the insertion of an inductive resistance, and the result is that there is a shifting magnetic field traversing the disc, which is thus subjected to a torque and revolves at a rate proportional to the current passing through the main coils. Owing to the peculiar shape of the magnetic circuit and the presence of the air gap *V*, the shunt current tends to make the lines of force traverse the air gap *V*, but the alternating current from the main coils creates lines of force through the disc, and the result is that during one-quarter of a complete period the lines of force due to the main coil assist in increasing the lines of force flowing round one-half (say the right-hand half in the figure) of the magnet, and during the second quarter of the period assist the lines of force flowing round the left-hand half. During the next half period the conditions are exactly reversed, the lines of force flowing in the opposite direction through the disc. The disc is therefore subject to four distinct alterations of magnetism during each complete period, but each alteration tends to make the armature rotate in the same direction. As the number of lines of force passing through the disc is exactly proportional to the current in the main coils, the meter can be calibrated so that the dials read in units. The action of the small compensating coil *C*, which consists of a few short circuited turns, is

to increase the magnetism through the armature, and so make it go a little faster and thus compensate for loss in speed due to mechanical friction.

In these meters calibration is so arranged that at the full stated current passing through them the revolutions of the armature disc is always 50 per minute; at half the stated current the revolutions will be 25, and so on; therefore, by counting the

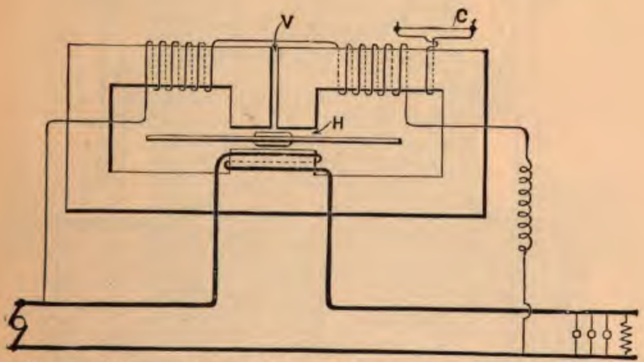


FIG. 3.—Diagram showing Electro-Magnet and Electrical Circuits of the Westinghouse Integrating Wattmeter

revolutions of the armature disc for a certain period at any given current, it can be quickly ascertained, without elaborate testing and reference to the dials, if the meter registers correctly. A magnetic brake, shown in Fig. 1, acts in exactly the same way as in the Chamberlain-Hookham meter already described.

Ferranti Meter.—This meter is perhaps more largely used than any direct current meter, and is very reliable and simple. It is a motor meter, and,

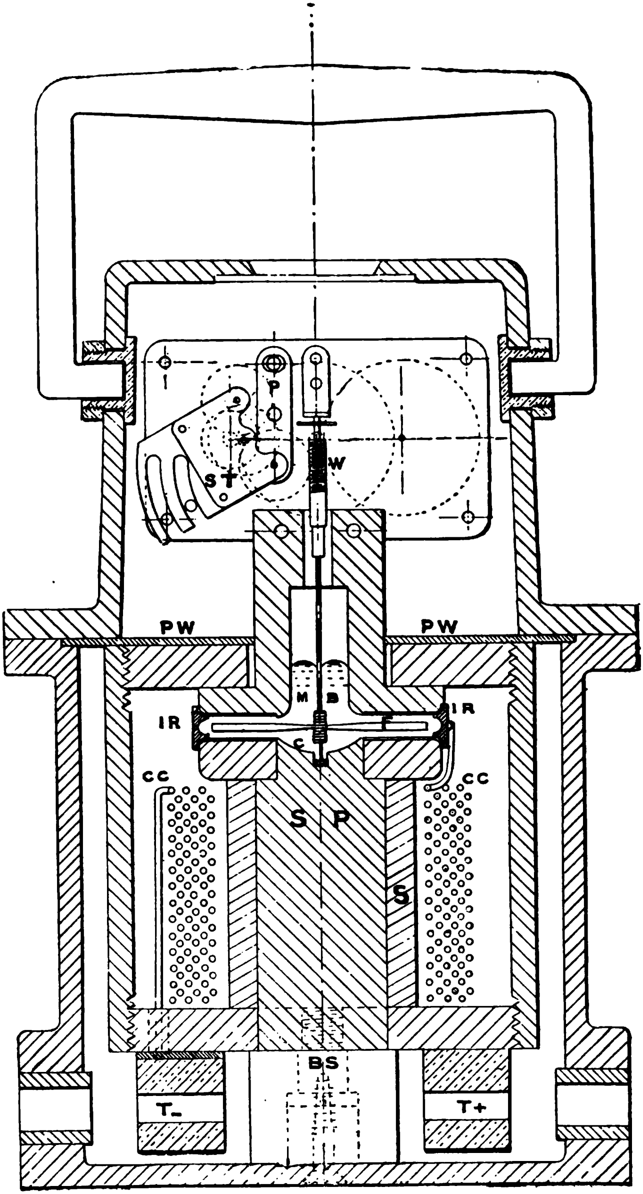


FIG. 1.—Section of Ferranti meter.

unlike other meters, only one pole of the electro-magnet is used to act on the current passing through

Fig. 2.—Ferranti meter.

the armature, which in this case consists of a bath of mercury. The motor may be described as a

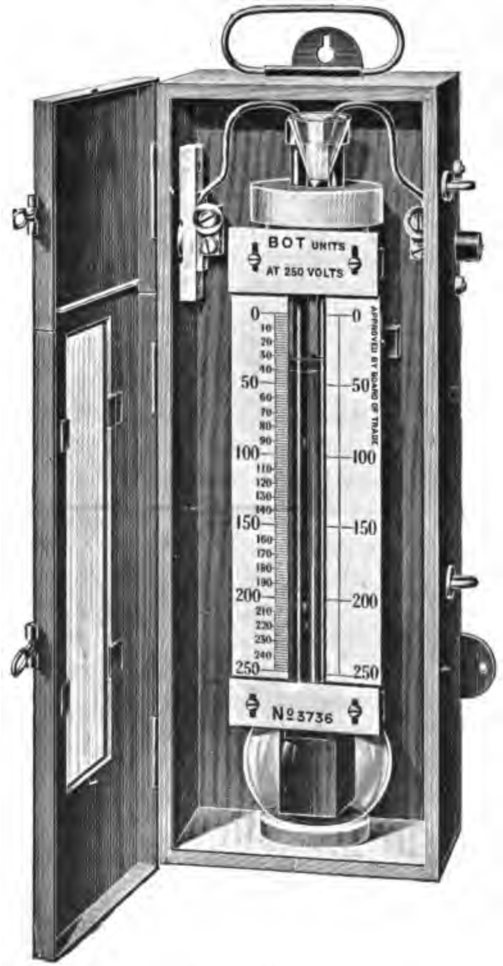
series wound unipolar motor, since the magnetic driving force is increased as the current increases in the coil surrounding the magnet. In Fig. 1 is given a section of the meter. The current entering at *T* passes up the steel pole *S P*, and enters the centre of the mercury bath *MB* at *C*; from this point it traverses the bath radially in every direction to the outer iron rim *IR*, and from this rim a connection is taken to the copper coils *C C*, and from these finally to the other terminal *T*. The mutual reaction of the radial currents and the electro-magnet would cause the mercury to revolve at a rate proportional to the square of the current, but as the fluid friction due to the revolving mercury varies as the square of the velocity, the resulting velocity of the mercury is directly proportional to the number of ampères passing through the meter. It must be borne in mind that in this meter *both* the radial current in the mercury and the magnetism in *SP* increase with increase of current; therefore the tendency is for the mercury to revolve as the square of the current passing through the meter. The light fan *F*, revolving in the mercury, transmits the motion to the train wheels at the top by means of a worm, *W*, and a very ingenious arrangement called the swing-plate. *SP* is introduced, whereby different ratio wheels can be conveniently introduced to enable the dials to read in Board of Trade units at any voltage. The steel pole *SP* is made permanently magnetic, so that the meter can start with a small current, and in order to avoid permanent increase of magnetism, which might take place due to a short circuit causing

a large amount of current to pass through the coil. the steel pole is surrounded by a soft iron cylinder, *S*, which acts as a protective shield. Fig. 2 shows the general appearance of the meter.

This meter as at present made is the result of very many years of hard work and patient research, and is thoroughly reliable.

Bastian Meter.—As mentioned above, this is an electrolytic ampère hour meter, and depends for its action on the fact that direct currents, when passing between electrodes, can split up water into oxygen and hydrogen. The amount of these gases produced, and therefore the amount of water that leaves the instrument as gases, is strictly proportional to the current passed through the meter. This meter is shown in the figure, and consists essentially of a glass tube open at the top containing acidulated water and two platinum plate electrodes. A graduated scale reading in Board of Trade units is placed at the side, and as the level of the liquid falls owing to the elements of water being given off as gas, the scale reading opposite the height of the liquid gives the number of units consumed. In order to prevent atmospheric evaporation a layer of oil is poured on the top of the liquid, and the junction line between this oil and the water acts as a pointer. A vulcanite frame at the end of the glass tube acts as a support to the electrodes, which consist of two platinum plates placed close to one another at the bottom of the tube, the leading-in wires being protected from electrolysis by vulcanite tubes.

These meters are suitable only for small currents,



Bastian Meter.

as the drop in pressure due to the passage of the current would be too great for heavy loads; up to 5 or even 10 ampères, however, they are largely used, but in any case there is probably a larger loss of pressure in these meters than in any other type. They can, however, be very cheaply made, and therefore command a large sale. As ampère hour meters they are very accurate, and they also register correctly very small quantities of current.

When the level of the liquid falls to the bottom reading of the scale the tube must be refilled with water till the zero mark is reached.

Meter Reading and Testing.—It is not easy for any one unacquainted with meters to read the dials accurately, so a few hints may here be given on the subject. On the dials of nearly all meters it will be seen there are arrows showing the direction in which the hands should move; if they move in the contrary direction the meter is not connected rightly to the mains. There are usually four dials, the left-hand one indicating "thousands" of units, and the others hundreds, tens, and single units. If now, for example, on the "thousands" dial the hand points, say, to the number 7, it is not safe to assume that 7,000 units have been consumed until the dial next on the right has been consulted; if this dial shows, say, 9, the true reading will be 6,900 odd, but if it shows, say, 1, the true reading will be 7,100 odd; similarly, in order to read the hundreds dial correctly, reference must be made to the next dial on the right. A little practice will enable any one to read meter dials correctly.

As a general rule meters are supplied and kept in order by supply companies for a fixed annual charge, and in cases of dispute they can be tested either by the engineers of the supply companies or by some independent authority. In London the London County Council have a meter-testing laboratory, and any meters can be tested by them for a small fee. In the appendix to this volume their regulations and scale of charges for testing are given. If a consumer doubts the accuracy of his meter and sends it to be tested, it is usual for him to pay the testing fee if the meter is proved to be accurate within 5%, but for the company to pay if the error exceeds 5%. In cases where the error is more than 5% an allowance is usually arrived at between the parties to compensate for the inaccuracy of the meter.

Appendix

REGULATIONS OF INSURANCE AND ELECTRIC SUPPLY COMPANIES.

OWING to the rapid growth of electric supply undertakings, and the dangers inherent in installations badly arranged, fire insurance officers issue regulations that must be complied with before the fire risk is taken over. The regulations of the different companies are made out on similar lines, and the best and most comprehensive are those issued by the Phœnix Fire Office. The rules of this company are given later in this chapter in full, and should be carefully studied, as any installation completed on the lines given in them cannot fail to be a success.[1]

The various supply companies also issue rules that must be observed before the connections to the mains are made. The rules in these cases refer more especially to the insulation tests required. As an example of the rules of a supply company those of the Westminster Electric Supply Corporation are given here.

In Institution of Electrical Engineers has also

[1] Mr. Musgrave Heaphy has kindly consented to the publication of these rules.

issued a series of rules embodying all that is best in the latest modern practice, and these rules touch on debatable points, such as the current density allowable in the smaller conductors and the fixing of cut-outs in ceiling roses, etc. Most of the points mentioned in these rules have already been discussed, but for purposes of reference they, too, are given here in full. With these rules are embodied extracts from the Board of Trade Regulations and Home Office rules for Mines.

THE PHŒNIX FIRE OFFICE RULES FOR ELECTRIC LIGHT INSTALLATIONS AND ELECTRICAL POWER, COOKING, HEATING INSTALLATIONS, ETC.

An excellent method of arranging an Incandescent Electric Light Installation is for the electrical mains after leaving the main switches and cut-outs (or cut-out) to be brought to an incombustible switch-board, split between the poles. The board should have "Bus Bars" in front, to which the mains should be attached, and 2-wire circuits should be taken from these bus bars, each circuit having a switch and a cut-out on the board for *each conductor*. If the circuits be large, they should be taken again to smaller boards of similar make and design to the above, and from these small 2-wire circuits not carrying more than 5 ampères when the electro-motive force of the current is 100 volts, nor more than 2½ ampères if the electro-motive force of the current is 200 volts, should be taken with a single switch [1] and double cut-outs on the board to each. When the circuits that leave the main board

[1] If the consumer desires still further security he might have two switches placed up instead of one.

are small, a single switch and double cut-outs for each circuit can be used, unless in certain special risks or cases.

CONDUCTORS.

Rule No. 1. Where practicable, all conductors in a building should be so placed as to be easily accessible, and capable of being thoroughly inspected whenever required.

Conductors should be accessible and not hidden away.

Conductors should not be run out of sight, such as between floors and ceilings, inside roofs, behind skirting boards, wainscoting, etc., if it can be avoided. No conductors to be run inside the roof of a theatre or other hazardous risk without permission.

No conductors to be placed where they or their insulation would be exposed to injury of any kind, either mechanical or otherwise, nor where they would be subjected to a temperature that might affect the insulation, nor where they or their insulation might be liable to be injuriously affected.

Conductors must be securely placed, must not be liable to deleterious influences.

All conductors should be of copper and their cross sectional areas must be such that at least double the maximum current to be carried by them could be safely used continuously.

Sectional Areas of Conductors.

By safety is meant that there shall be no perceptible heating of the conductors to the touch ; and when proportioning the sizes of conductors, the possibility also of their sectional areas getting diminished by corrosion, mechanical injury, etc., as time goes on, must never be forgotten ; the importance of taking this into account cannot be over-rated.

Safety.

The conductivity of the copper must not be below 100 per cent. of that of pure copper (Matthiessen's Standard).

Conductivity.

The quantity of current sent through a copper conductor *must not* exceed the ratio of 1,000 ampères per cross sectional square inch, provided the amount passing through the said conductor does not exceed

Ratio of Current per cross sectional square inch of Conductors.

100 ampères ; should the amount of current exceed 100 ampères, the ratio of course must be less.

The ratio will vary according to the quantity of current beyond the above-mentioned amount sent through a conductor.

Should conductors be exposed to an external temperature of over 100 degrees Fahr. then the ratio of current per cross sectional square inch of copper must be below that above mentioned. The ratio will depend upon the temperature and the amount of current to be carried.

Lamps not to be considered as less than 16 candle-power.

In proportioning the sizes of the conductors, incandescent lamps must not be considered less than 16 candle-power each, unless special permission to the contrary be given.

Stranded Conductors, etc.

Smallest size of Conductors.

All conductors of a larger sectional area than No. 16 S. W. G. to be composed of strands. No conductor of less size than No. 18 S. W. G. should be used except in fittings, and in these no conductor should be less than No. 20 S. W. G.

It is as well to arrange the work, when it can conveniently be done, so that not more than 100 ampères pass down any single conductor.

The use of copper is not obligatory in all cases, but permission must be first obtained if any other metal be used for wiring purposes.

Tinning of Conductors.

When insulated copper is used the copper should be double "tinned" or otherwise protected from the possibility of any injurious action upon it from the insulation.

Naked Conductors not allowed.

No. 2. No naked conductor, or conductors, allowed in a building.

Unless in those cases for which special permission has been obtained to use naked conductors.

Insulation of Conductors.

Insulation of Conductors.

No. 3. All conductors (except those for certain special risks or places) must be highly insulated with very substantial coats of india-rubber of the highest quality, *which must be specially prepared to last*, and which must be of approved thicknesses [or other

specially approved equally good material that will not too readily become plastic or brittle, that is impervious to moisture, and of lasting quality, and to use which *special permission in writing* has been obtained from the Technical Adviser of the Fire Office]. With regard to the coats of india-rubber, the outer ones must be of vulcanizing india-rubber, but the ones next the metallic conductor must be of pure india-rubber (unless permission to the contrary be given), and the whole taped and properly vulcanized together, and the insulation should be further protected by strong and durable coverings such as braided hemp, and the like, which should also be so treated as to be impervious to moisture. The insulation should be as uninflammable as practicable, regard of course being had that neither its efficacy nor its durability is in any way diminished thereby; and the insulation must contain no ingredient that would injuriously affect the metallic conductor it insulates, unless efficient safeguards have been taken to protect the metallic conductor from any possibility of such injury.

Tubular form of Insulation.

The insulation on a conductor must be in the form of a homogeneous tube, and it is desirable that the india-rubber composing the tube be as thick as possible.

No material or materials will be allowed to be used under any circumstances for the purpose of insulation, except those that are approved by the Technical Adviser of the Fire Office. The composition, quality, thickness, make and resistance of the insulation of all conductors must be to his entire satisfaction.

When the conditions of any Risk or place are such that india-rubber or any other approved insulation could not be safely used, notice must be sent to the Fire Office for their consideration and decision, before any work is commenced.

Insulation Resistance of Conductors.

Nothing is stated above as to the resistance required in the insulation of conductors before being placed up in a building; so many cases having occurred of insulation that has given

extremely high results so far as tests are concerned before being placed up, breaking down after having been in use for a short time. What really is required is an insulation that will last, even though its resistance may not have been originally so very high. It may be mentioned however that, for electrical installations in which the pressure is not above 250 volts, the insulation resistance of conductors before being placed up should not be less than 600 megohms per mile in dry places and 2,000 megohms per mile in damp places. The tests must be taken with an electro-motive force of not less than 500 volts after the cables have been immersed in water at 60 degrees Fahr. for 24 hours, and with one minute's electrification. When the pressure is above 250 volts the insulation resistance of the conductors before being placed up should not be less than 2,000 megohms per mile.

Enclosing or Encasing of Conductors.

Conductors to be enclosed or encased.

No. 4. In non-hazardous risks the conductors having been thoroughly well insulated, as described under Rule 3, should (except flexible twin wires) be enclosed in iron or other approved welded or solid drawn metal tubes, or in other approved fireproof tubes; or in substantial wood casing (unless wood casing be objected to by the Fire Office).

Metal tubes (or pipes).

No tube, nor arrangement of tubes will be allowed, that is not approved by the Technical Adviser of the Fire Office. No tube will be allowed of any material that does not meet with his approval.

(It may be mentioned that no soft metal tubes, nor metal tubes that could easily be melted are allowed; nor wires sheathed with soft or easily melted metal for protection in lieu of approved metal tubes. Except when the circumstances are such that the Technical Adviser to the Fire Office considers their use desirable, or necessary.)

Metal tubes must be firmly fixed or supported They must be kept at a perfectly safe distance from all gas pipes, and bell and telephone wires, etc., and from all metal work not forming part of the installation.

All iron or steel tubes should be solid drawn, or welded, and their joints thoroughly well screwed—metal to metal. They must be bushed where necessary

All metal tubes should be of substantial thickness; they must be provided with proper metal junction boxes.

No metal tube to contain an open seam.

Metal tubes must be so arranged and laid, that moisture could not lodge or get inside them, nor be able to injuriously affect the conductors they contain.

Several conductors (when forming part of the same system of lighting) may be placed in a single iron tube, except when not considered desirable by the Fire Office.

When alternating currents are used, conductors must not be placed separately in metal tubes.

Metal tubes to be earthed, etc.

When a system of metal tubes is employed, the metal tubes and boxes must be properly earthed (except where earthing in any special instance is objected to or considered undesirable by the Fire Office). The tubes should be electrically and mechanically continuous.

Wood casings.

When wood casing is used, the casing must be composed of sound, hard, well-seasoned wood. The conductors must be kept apart by a continuous fillet or width of wood, which should be at least 1 inch in breadth in the case of the mains and principal branches, and ½ inch in breadth in that of the smaller circuits or branches. The covers of the casing should be substantial and screwed on, they should be screwed at the sides; the covers for large casings should be screwed at the centre as well as at the sides. Brass screws should be used.

Wood casings should be used for surface work only, they must not be hidden away (unless permission to do so has been previously obtained from the Technical Adviser of the Fire Office.)

Wood casings must be most firmly fixed, and the mitreing most carefully done.

The inside of the casings must contain no sharp angles along the path of the conductors, all corners must be rounded.

Wood casings must not be employed when the pressure of current used exceeds 250 volts.

There must be no crossing of wires in wood casings.

Wood casings and wiring joints.

No wiring joints should be in wood casings without permission. When allowed they should not if possible be immediately opposite each other, but as far apart as can conveniently be arranged.

Unenclosed Conductors.

In no instance are conductors to be run unenclosed, unless special permission to do so has been given by the Fire Office.

When permission has been obtained to run conductors unenclosed, then the conductor should be kept at least 4 inches horizontally apart, and no conductor should be less than 4 inches from any conducting substance, unless special precautions against contact have been taken. The conductors must be in secure positions, not liable to injury, rigidly fastened to approved porcelain or earthenware insulators, and kept at least 4 inches from the wall or material to which the insulators are fixed. When the electro-motive force exceeds 250 volts, the distance the conductors should be kept apart from each other and from conducting substances will depend upon the pressure of the current, and the surrounding circumstances, and be decided as each case arises.

In no case should the supports for any conductor be so far apart that if the conductor broke either end could reach the floor or ground below.

Conductors exposed to external injury.

When external injury is possible conductors must be enclosed and protected in a manner that will absolutely prevent any injury accruing to them or their insulation.

Conductors in Hazardous Risks.

In hazardous risks all conductors should be very highly insulated and enclosed in iron, steel, or other approved metal tubes as previously described; or when not objected to by the Fire Office, laid in sound, hard, well-seasoned wood casing, which has been thoroughly well treated with an approved fireproof

paint or compound, or laid in approved fireproof wood casings; the casings must not be hidden (unless permission has been previously obtained from the Technical Adviser to the Fire Office to do so).

Or such other precautions may be required that may be considered requisite having regard to the circumstances of the risk.

For central stations, theatres, mills, and other very hazardous risks, see Rule No. 36.

Special Precautions may be required if current is above 250 volts pressure.

In all risks, if the electric pressure of the current used is above that of 250 volts, special precautions other than those above stated, and varying according to the electro-motive force employed and the surrounding conditions, may be required, if considered necessary.

When the current is of very high pressure, then the conductors may have to be encased and kept apart as described in Rule No. 26, for the primary conductors carrying alternating currents to secondary generators, or be arranged in such other special manner as may be decided, having regard to all the circumstances of the case and the risk.

Metal Tubes or Piping (General).

Great care must be taken with regard to the jointing of metal tubes (or pipes).

Junction boxes should be of cast-iron, when possible.

No non-fireproof tube will be allowed without permission.

The interiors of metal tubes might be lined with an approved insulating compound, but this is not obligatory unless required by the Fire Office.

The interiors of metal tubes must be perfectly smooth, so that when conductors are drawn in or out their insulation will be uninjured.

Bunching not allowed without permission in wood casing in Hazardous Risks.

There must be no "bunching" of positive conductors together, or of negative conductors together, in wood casing in any hazardous risk without permission. No "bunching" will be allowed in any place or in any risk that may be deemed undesirable by the Technical Adviser of the Fire Office.

Wood casings and fireproof paint, etc.

It is preferable that wood casings in non-hazardous risks be treated with an approved fireproof paint or compound, in order to render them as non-inflammable as possible. It is sometimes desirable to putty the joints of wood casings.

Cement and Putty.

Care must be taken to ensure that any cement or putty that may be used contains no oil or other ingredient that would be injurious to the insulation of the conductors, or would in any way cause the insulation resistance to be lowered.

Conductors must not be laid in wet materials, etc.

Conductors should never be laid in brickwork, concrete, cement, plaster or like materials, whilst the same are wet, or while they are drying, if there is any liability of the conductors or their insulation being injured thereby.

Lamps in Series.

When lamps are in series, the minimum distance apart of any two conductors (or portions of the circuit), must be regulated by the difference of potential between such conductors (or portions of the circuit).

Lamp Fittings.

The small conductors about lamp fittings cannot always comply with Rule No. 4. The work, however, in connection with them must be of a thoroughly secure character.

Flexible Twin-Wires and Cords.

Flexible Twin-Wires.

No. 5. As little flexible twin-wires or cords should be used as possible.

Flexible twin-wires and cords should be kept well away from the vicinity of inflammable materials, be very carefully protected by cut-outs, their insulation should be substantial and protected as much as possible against abrasion or injury of any kind. Flexible twin-wires should not be in any position where they could make an earth, nor must they be hidden away. Too much attention cannot be bestowed to this.

Flexible wires or cords must not be knotted either inside a ceiling rose or elsewhere.

No more than one pair of flexible wires should be attached to a ceiling rose, wall plug, etc.

Flexible twin-wires should not be used for wiring electroliers or fittings.

Twin wires should not be used in Risks containing very Inflammable materials, etc.

Twin flexible wires (or cords) should not be used in mills, factories or other hazardous risks containing very inflammable materials, especially if the materials be immediately under the lights. It is far preferable in these circumstances that fixed lights only be used.

No flexible twin-wires or cords to be used when the

pressure of current is above 250 volts without permission.

All twin-wires and cords, and the positions in which they are placed, must be to the satisfaction of the Technical Adviser of the Fire Office.

No flexible twin-wires or cords to be placed out of sight, such as between floors and ceilings, inside walls, etc.

Twin-wires and cords are not allowed in certain risks without permission.

Frequent examinations of twin-wires and cords should be made.

The insulation resistance of twin-wires or cords before being placed up should not be less than 300 megohms per mile.

Hidden Conductors.

No. 6. If conductors have to pass between floors and ceilings, inside roofs, behind wainscoting, or otherwise out of sight in buildings, they should (unless permission has been obtained to the contrary) be enclosed in approved metal or other fireproof tubes, except the circumstances be such that metal tubes would not be desirable. Under some circumstances the precautions with regard to hidden work require to be very special. Hidden Conductors.

No conductor carrying a current of over 250 volts to be laid out of sight, between floors and ceilings, behind wainscoting, etc., without permission.

Conductors Exposed to Moisture, etc., Unfinished Buildings, etc.

No. 7. All conductors liable to damp or moisture in a building must not only have thoroughly waterproof insulation, but the greatest care must be taken that they are also enclosed in such a secure manner that it would be impossible for moisture to get to or affect them. The enclosing material should be completely waterproof, of lasting character, and fireproof. Conductors exposed to Moisture, Damp, etc.

Too much care cannot be taken with regard to this matter.

Conductors in unfinished buildings, etc.

When any electric work is being placed in buildings during course of construction, or before the buildings are "dry," the utmost care must be taken to protect it against any injurious action it might be subjected to, either from damp or other cause; from neglect of taking these precautions great trouble has arisen in installations; conductors, joints, insulation, wood casing, etc., having been quickly eaten away or destroyed. Wood casings must not be used in floors or walls, etc., or in any place where they might be affected by damp or moisture given off by the building. All work in a building, such as above described, should be "special." An electrical contractor should never be required to place up work in a building if it be not sufficiently "dry."

Work inside roofs.

Wood casing must not be laid inside any roof; approved metal or other fireproof tubes should be used, and in such a manner that moisture could not get inside.

Conductors not to be placed under Water Pipes, etc.

Electric work must not be placed underneath water pipes, cisterns, pavement gratings, or pavement lights, or in any place where moisture could get to any part, unless special precautions have been taken to thoroughly protect it against the same.

Conductors Attached Externally to Buildings.

External Conductors.

No. 8. Conductors attached externally to a building must, unless permission to the contrary be given, be insulated, and the insulation must be of a waterproof and durable character, calculated to resist deterioration from atmospheric influences.

When conductors run along the outside of brick or stone walls of a building and are not enclosed in iron tubes, they should be fastened to approved porcelain or earthenware insulators, and kept well away from

the walls, and from each other, and at such a safe distance from any woodwork or combustible material that if the conductors were to fire, there would be no possibility of the woodwork or building being affected. The supporting insulators should be sufficiently close to each other for the conductors to be run rigidly, and so prevent undue swaying under the action of winds and storms.

Conductors must not run along the walls of wooden buildings without permission.

Must not run along Walls of Wood Buildings.

The insulation, fixing, general arrangement, safeguards, etc., of all external conductors attached to buildings must be to the sa isfaction of the Technical Adviser of the Fire Office.

Overhead conductors supported by poles on roofs will be considered as being attached to those buildings on which the poles are situated.

Overhead Conductors.

External conductors must, where necessary, be protected by lightning dischargers in accordance with Rule No. 34.

Conductors Passing through Exterior Walls.

No. 9. All conductors passing through the exterior walls of buildings must be insulated and enclosed in separate earthenware or approved metal tubes (except when alternating current used), or laid in an approved fireproof cement not injurious to the insulation.

Conductors passing through Exterior Walls.

The arrangement must be such as not only to prevent moisture entering, but also as far as possible fire penetrating from the outside by running along the conductors.

Conductors must never enter a building through the roof.

Conductors. Party Walls. Lifts.

No. 10. Conductors must never pass through party walls separating two risks, unless permission to do so has been given; and when this has been obtained, provision must be made to the satisfaction

Conductors not to pass through Party Walls without permission.

of the Fire Office with the object of preventing fire being communicated from one risk to the other by means of the conductors.

No Electric Work to be on or in Wood Lifts.

No electrical work of any kind to be placed on the walls of lifts when of woodwork.

No electric work to be carried up wood lifts. When conductors pass up brick or stone lifts, special precautions may in some cases be required.

Conductors. Joints, Fastenings, etc.

Joints.

No. 11. There should be as few joints in conductors as possible. It is far preferable that there be none at all. Joints should not be placed in wood casings without permission. All joints must be most carefully made, soldered and insulated. The insulation of joints must be as perfect as possible, of a lasting character and waterproof ; special care must be taken to guard against moisture getting to the joints.

Insulation of Joints.

Joints should be highly insulated with layers of rubber strip with rubber solution between, and then layers of prepared binding tape with rubber solution between, and when possible, a vulcanized rubber sleeve drawn over the whole.

Under certain circumstances the insulation of joints should be vulcanized.

Carrying Capacity of Joints, etc.

A joint should have a greater carrying capacity than similar lengths of either of the conductors it unites.

Surface.

The surface of a joint should be smooth after soldering, and have no projecting points that might tend to pierce the insulation.

Resin to be used when Soldering, etc.

Resin should be used when soldering. Great care must be used when soldering that the solder catches everywhere, and that no resin is left in the interstices between the wires.

No joint to be exposed to Moisture.

No joints should be placed in situations where there would be a liability of moisture getting to them.

Where conductors are run in metal tubes metal junction boxes should be provided for joints. Junction Boxes and Joints.

All conductors carrying over 5 ampères at 100 volts pressure should be sweated into thimbles when connected to switches, cut-outs, distributing boards, etc.; the work must be carefully done and finished off. Thimbles.

Bare connections must be so mounted and situated that no danger could arise in the event of their heating. They must be so mounted that leakage of electricity from them could not take place. All connections must be as perfect as possible. Bare Connections.

The fastenings of conductors must be composed of approved non-conducting material. When metal staples are allowed to be used, a piece of india-rubber, or other approved insulating material, should be inserted between the head of the staple and the insulation of the conductor. Metal staples ought not if possible to be used, saddles or cleats of an approved insulating material being preferable. Fastenings of Conductors.

Cut-Outs.

No. 12. All conductors must be protected by cut-outs (except in those cases and places where cut-outs would not be considered desirable by the Fire Office). Cut-outs.

Wherever a branch is led off any conductor to supply current for incandescent lamps, or for any other purpose, a short length, of lead, tin, or other approved fusible metal or substance, must be inserted at the junction of the branch with the conductor; and the lead, tin, or other fusible metal or substance, must be of such section, length and nature, that if the current passing through it exceeds the normal current by 50 per cent., then it will fuse and disconnect the branch. In those circumstances where it is conveniently practicable to have cut-outs that will fuse at a less excess above the normal than 50

per cent. they must be placed in. All cut-outs should be proportioned to fuse at as small an excess above the normal current as is compatible with the proper and efficient working of the lights, and be enclosed in approved fireproof boxes, when not placed upon enclosed incombustible distribution boards. Porcelain, earthenware, or iron boxes (in some instances lined inside with a fireproof insulating material) are preferable to use. Cut-out boxes must be of an approved type.

When the maximum amount of current carried by a branch or small circuit does not exceed 4 to 5 ampères, and the pressure of current is not above 100 volts, and this branch or small circuit is provided with a "cut-out" on each pole, then the Technical Adviser of the Fire Office may give permission (unless he considers it unadvisable) for no other "cut-outs" to be used between those above-mentioned and the lights. (And the same will apply when the current carried does not exceed 2 ampères at a pressure of 250 volts).

Definition of Branch.

By "branch" is meant any conductor issuing from another of great sectional area.

If any conductor, by re-uniting with any conductor, or by any other arrangement, becomes technically part of the main, it may still be considered as a branch if its sectional area is less than the conductor it issues from, and will require to be protected as such.

Length of Break of Cut-outs.

Cut-outs should not have less than a clear inch break for currents up to 100 volts pressure, nor less than one-and-a-half inches for currents of from 100 to 200 volts, nor less than two inches for currents of from 200 to 250 volts; *the break must be of such a length and so arranged that an arc could not be sustained between the terminals of the cut-out. The quantity of current passing, as well as its electro-motive force, must also be taken into consideration when determining the length of break of the cut-out.*

The length of break for cut-outs when over 250 volts are used will depend upon the electrical measure employed and, of course, the quantity of current that is to pass through the cut-outs.

All principal branches, and branches having a considerable number of lights, and all circuits from distribution boards must have cut-outs on both poles. Small branches, taken off conductors of much larger size, and the branches supplying current to fittings containing several lights, should have cut-outs on both poles.

Cut-outs to be on both Poles of Branches and Circuits.

When the pressure of current is 100 volts, no branch carrying 4 ampères or upwards should be without cut-outs on both poles.

All "cut-outs," including the materials of which they are composed, and the positions in which they are placed, must meet the approval of the Technical Adviser of the Fire Office; many cases having occurred of "cut-outs" failing to act when required, and even, sometimes, themselves being the cause of a fire: they must never be placed under floors, inside roofs or behind waincoting, or skirting-boards, or in wood cupboards, etc., unless *special* permission to do so be given by him and the safeguards adopted are to his satisfaction. All cut-outs must be so arranged and mounted that no fire or danger could arise in the event of their heating, or fusing, or arcing.

All Cut-outs to be approved by Fire Office.

Cuts-outs not to be hidden away.

The main conductors, both positive and negative, must have their cut-outs placed as near the dynamo (or source of electricity) as possible, or if the current is supplied from a central station they should be at the entrance of the conductors into the premises, and the cut-outs, like those of the branches, must be proportioned to fuse at as small an excess of current above the normal as is practical and compatible with the efficient working of the installation. The excess above the normal must not exceed 50 per cent. without permission.

Cut-outs Main Conductors.

Earthed System.

When one main of a system is allowed to be earthed, that main is not to have a cut-out unless required by the Fire Office, to whom full particulars must be sent.

Middle Conductor of a 3-wire system.

In a 3-wire system no cut-out is to be placed on the middle conductor unless required by the Fire Office.

Cut-outs (General).

If a branch is already protected by "cut-outs" on the mains, or on a superior branch, then it may not be necessary to again protect it by other "cut-outs," unless required to do so by the Fire Office.

The Technical Adviser of the Fire Office may give permission, under certain circumstances, for a larger proportion of current than 50 per cent. above the normal to be carried by a cut-out.

When lights are grouped, as upon electroliers, etc., care should be taken that the last controlling "cut-out" carries as small an amount of current as practicable, and that it will act before the smallest wire runs any risk of getting unduly heated.

Maximum Current to be carried by Ultimate Distributing Circuits.

When an incandescent installation is arranged with distributing boards, the ultimate distributing circuits should carry as small an amount of current as possible —not more than from 4 to 5 ampères, if the pressure of the current is 100 volts, nor more than 2 ampères if the pressure is 250 volts, and be protected by "cut-outs" on both poles.

Cut-outs, Arc Circuits.

With regard to arc circuits, or when incandescent lamps are arranged in series, the question as to whether fusible "cut-outs," or what other kind of "cut-outs" should or should not be used, will be decided as each particular case arises; so much depending upon the arrangement of the lights and the system of lighting. When arc lights are arranged in parallel, the conductors must have "cut-outs."

Magnetic Cut-outs, Circuit Breakers, etc.

Should it be desired to use magnetic "cut-outs," or any other kind of "cut-outs" or circuit breakers, *instead* of fusible "cut-outs," permission must first be obtained. *Cases may occur where fusible "cut-outs" should not be used.*

Switches.

No. 13. The main conductors must have switches on both poles; and the same arrangement should be carried out on all the principal branches. *The arrangement should be such that the current can be entirely switched off from the lights and electrical work in any particular portion of the building the occupier may desire.*

A Switch to be on each pole of Mains and on principal Branches.

The last controlling switch should carry as small an amount of current as is conveniently practicable; not above 5 ampères if the pressure is 100 volts, nor above 2 ampères if pressure is 250 volts.

Last Controlling Switch.

It should never be forgotten that turning off a single switch, although it puts out the lights, does not turn off the electricity, which is still on, and under certain circumstance smight break out and fire the place. *All the principal portions of a building, therefore, should be controlled by a switch on each pole of the conductors supplying them with electricity.*

Conductors in principal portions of a Building should have Switch on each pole.

All switches to be of such construction and make that they will not be liable to get out of order, or heat, or fire. Their construction should also be such that it would be impossible for them to remain in any intermediate position between full on and off.

Construction of Switches.

All switches must be mounted and placed in such a secure manner that no fire could arise in the event of their heating or arcing. They must also be so mounted that leakage of electricity from them is prevented. Their rubbing surfaces should be large and their break quick; the break of the switch must be of such length that an arc could not be sustained.

Mounting and placing of Switches.

Switches must always have an incombustible base, the insulation of which should be perfect; no metal work carrying current should be exposed at the under side of the base; they must have an approved incombustible cover, when not on an incombustible distribution board; the switches should be kept perfectly

free from moisture ; their fastening screws should not come into contact with the wall upon which the switches are placed, but be separately fixed into an insulating block.

KEY SOCKETS OR SWITCH HOLDERS.

Key Sockets or Switch Holders.

No. 14. With regard to switches contained in the lamp holders ("key sockets"), these will be allowed only in those places and under those circumstances for which permission has been obtained from the Technical Adviser of the Fire Office.

MAIN SWITCHES, ETC. TENANTS' SWITCHES.

Main Cut-outs and Switches must be at points of entrance of Conductors.

No. 15. Every conductor must have a cut-out and switch placed on it at its point of entrance into a building when the current is generated externally ; and the conductors for this purpose must be brought into the building in as perfectly secure a manner as possible to a suitable place for fixing up these cut-outs and switches in thoroughly secure and accessible position. The switches must be so arranged that they always act together—that is, one cannot be turned on or off without the other.

A Cut-out and Switch to be on each Main in a Dynamo Room.

When the source of supply is internal, then a cut-out and a switch should be placed in the dynamo-room on each conductor from the dynamo or dynamos, unless, in the opinion of the Technical Adviser of the Fire Office, these cut-outs or switches might be dispensed with.

If, however, a 3-wire system is employed, no "cut-out" is to be on the middle conductor, as stated in Rule No. 12, unless required by the Fire Office.

Tenants' Switches.

When a building is in the occupancy of various tenants, each tenant must have a cut-out and a switch on each pole of his service conductors, and so placed as to enable the current to be entirely cut off from the branch that supplies this tenancy. The

conductors must be brought in in a perfectly secure manner for the safe placing up of these switches and cut-outs.

A cellar may be considered as a building or part of a building from a fire point of view, unless in the opinion of the Fire Office there are circumstances that would not warrant this.

A Cellar may be considered as a Building or part of a Building.

Switch Boards and Distribution Boards.

No. 16. Switch boards and distribution boards should be composed of a non-conducting fireproof material. They must be fixed in dry and secure places and be most carefully mounted; the arrangement of the work in connection with them, especially at the back, should be such that if a fire broke out at the board, the fire would have difficulty in spreading. The wall behind the boards should be incombustible, and the work at the back of the boards easy of access.

Switch Boards and Distribution Boards. Construction and arrangement, etc.

The boards must not be placed on match-boarding, nor on wood walls—especially of lifts—nor on wood fittings, etc.

Caution as to position.

The boards should be "split," i.e., the positive portion separated from the negative part; the conductors should be brought to metal "bus" bars upon them, from which circuits should be taken, each circuit having a cut-out and a switch on each pole, except small circuits, which could have a single switch on one pole, but a cut-out on both poles. The conductors should be sweated into thimbles. The nuts on screw fastenings should be locked.

Construction and arrangement, etc.

The "bus" bars, switches, cut-outs, instruments, etc., must all be on the face of the board, and not behind. The conductors at the back should be most carefully arranged and opposite poles kept well apart as far as possible.

The switch boards and distribution boards should have an incombustible case with glass front, but

teak, oak or mahogany cases with glass fronts, are allowed except under certain circumstances. Main switch boards in certain instances will not come under this regulation.

Wood cases must be lined inside with approved incombustible material when required by the Fire Office.

In large installations and in hazardous risks, the main switch board and its surroundings should not only be incombustible, but there should be sufficient space at the back of the main board to enable a man to comfortably get behind and attend to any matter, unless in the opinion of the Technical Adviser of the Fire Office such precautions are not necessary.

In certain special risks the switch boards may have to be enclosed in iron cases.

Resistances. Choking Coils.

Resistances, Choking Coils, etc. to be very securely mounted and placed.

No. 17. All resistances, choking coils, etc., must be mounted and placed so securely that no danger could arise in the event of their heating. They must be so mounted that leakage of electricity from them cannot take place.

Resistances should be in approved Metal Boxes and on Brick or Stone Walls.

Resistances must be securely mounted upon approved incombustible material, and placed in very secure positions, well away from all combustible materials; they must be enclosed in approved metal or other approved fireproof cases or boxes but insulated therefrom, and fixed to brick or stone walls by porcelain or earthenware insulators, unless permission to the contrary be given. Many fires have been caused by resistances, and it is impossible to over-rate the importance of their being securely mounted and situated. The arrangement should be such that if they got red-hot, no damage from fire would result.

Resistance Boxes.

Upon the outside of the metal box containing the resistances there should be a legible statement giving

the maximum temperature the resistances are to attain; and the arrangement and size of the box should be such that its temperature would be but very slightly raised when the resistances are at their maximum temperature.

Care must be taken that dust or fly, etc., would not be able to get to or accumulate about the resistances.

Choking coils should be treated as resistances. **Choking Coils.**

Incandescent Lamps.

No. 18. An incandescent lamp as referred to in these rules, and for which permission to use is given, signifies an exhausted and hermetically sealed glass bulb containing a filament of carbon (or other suitable substance) connected with the exterior of the bulb by connecting wires, for conveying electricity to the filament to render it incandescent. **Definition of an Incandescent Lamp.**

All combustible materials must be kept at a perfectly safe distance from incandescent lamps. Incandescent lamps have sometimes got exceedingly hot, and been the cause of fires. Incandescent lamps must be so mounted and placed that no danger would result in the event of their heating. **Safe placing of Incandescent Lamps.**

Incandescent lamps, when so situated that inflammable dust or fly could settle on them, or moisture get to them, should be securely enclosed again in proper protecting globes. The holder should be enclosed also. **To be further enclosed in some cases.**

Incandescent lamps in shop windows should be fixed ones, and kept well away from combustible goods and materials, or other goods or materials that might be damaged by heat. The lamps should be so placed, or the arrangement such, that combustible goods or materials could not come into contact with them. **Lamps in Shop Windows, etc.**

Efficient protecting guards should be placed over incandescent lamps when so situated that combustible materials might come into contact with them. **Guards.**

Lamps and Holders. When placing incandescent lamps in the holders care should be taken that they fit properly and make good contact, or heating may arise.

Lamps of over 50 c.p. When in any hazardous risk it is desired to use incandescent lamps of above 50 candle-power each, permission should first be obtained.

Incandescent lamps should have the voltage and candle power indelibly marked on them.

Lamp Holders, Caps, Shades. Ceiling Roses. Wall and Floor Sockets

Lamp Holders. Construction, etc. No. 19. All lamp holders must be incombustible, and of an approved type; their terminals must be separated by an approved insulating bridge. It is sometimes preferable to solder the ends of flexible wires, when composed of fine strands, before attaching them to the holders.

Caps. All lamps caps should be able to stand 100 per cent. more pressure of current between the two contained terminals, or between either terminal and the collar, than will be employed in the lamps.

Shades should be incombustible. All lamp shades should be incombustible.

No combustible shade to be in contact with an incandescent lamp, but must be well away.

Celluloid, etc., not allowed. No shade made of celluloid or analogous substance allowed, nor of any material objected to by the Fire Office.

Ceiling Roses. Construction, Fixing, etc. All ceiling roses must be of an approved kind; they should be composed of an approved incombustible material and most carefully made and fixed. Their constuction should be such that no strain can be thrown on the pendant wires at their terminals in the roses. Ceiling roses should be fastened to back blocks composed of approved material.

Cut-outs in Ceiling Roses. When the electro-motive force of the current used is 200 volts or above, cut-outs will be allowed only in those ceiling roses that have been specially designed

for the same, and previously approved by the Technical Adviser of the Fire Office.

In certain Risks ceiling roses must not contain cut-outs.

No wall or floor sockets with flexible conductors therefrom will be allowed in any place or in any risk that the Technical Adviser of the Fire Office may consider to be unadvisable. All wall or floor sockets must be of an approved kind and composed of an approved incombustible material, and the greatest care must be exercised in fixing them. The flexible conductors should be most substantially insulated, and the insulation well protected against injury. **Wall and Floor Sockets. Construction, Fixing, etc.**

Floor sockets are not allowed, unless permission to use them has been obtained. They should be provided with an approved incombustible lid or cover to close over the contact orifices when not in use.

When portable lamps are used with flexible cords from wall sockets, the particular circuit supplying the current to the sockets should carry as small a quantity of current as possible, and be provided with double cut-outs and double switches. A cut-out may be required for each socket under certain circumstances. **Sockets and Portable Lamps.**

Imitation Candles.

No. 20. Imitation candles must be incombustible and of approved construction. **Imitation Candles.**

Arc Lights.

No. 21. An arc light as referred to in these Rules signifies one in which the light is produced by the passage of electrical current across a gap between two conductors. **Arc Lights.**

If arc lights are used, they must be completely enclosed in approved porcelain or glass globes. The globe should have a metal plate at the base,

and any necessary arrangement for ventilation at the top must be so constructed that no sparks or flame could escape ; the globe should be substantial so as not to readily break if a carbon fell or burst. The globes must be covered round with wire netting, unless permission to the contrary be given, and they must be at a safe distance from all combustible materials. The resistances must be apart from the lamps,

No naked arc lights allowed without special permission.

Must not be supported by their Conductors, etc.

Arc lamps must never be supported by their conductors either wholly or in part. Arc lamps must be thoroughly well insulated from their supports.

When arc lights are run in series, means must be taken for maintaining the constancy of the current, whatever number of lamps may be burning.

Arc Lights in Cotton Mills and hazardous risks.

In cotton mills and certain other mills and hazardous risks if arc lamps are allowed to be used, they must, unless of inverted type, have two globes, each completely and independently surrounding the arc, and the lamps should be of such design and make that the arc could not be sustained unless the inner globe remained intact : but in any case the lamps must be such that they are dependent for proper action upon one of the two globes being intact. Arrangements should be made to guard against the possibility of explosion from the gases produced. If, however, the arc lamps are of inverted type, they must have unbreakable and irremovable reflectors beneath them, projecting at least 21 inches beyond the arc on every side horizontally, and the arc at all times set below the level of the upper edge of the reflector ; or if the reflectors do not project 21 inches beyond the arc on every side horizontally, have the arc completely surrounded on all sides, either by a glass globe, or by a glass dome, extending from the face or edge of the reflector upwards.

When arc lights are proposed to be installed inside a building, especially if it be a hazardous risk, particulars of the kind of lamp to be used, including the number of ampères it takes, should be sent to the Fire Office. **Arc Lights. Particulars to be sent.**

When permission to use arc lights in a building is given, the permission is for arc lights taking not more than 12 ampères of current each, unless otherwise stated. **Current.**

In certain risks arc lights are not allowed.

Electroliers.

No. 22. Electroliers must be most carefully and securely fixed and arranged. The wiring must be of a most secure and lasting character, and carefully arranged so that it would not be liable to mechanical injury. **Electroliers.**

All electroliers and fittings must be composed of incombustible materials.

Gas Work and Electrical Work.

No. 23. Electrical work must not be situated in confined spaces containing gas pipes without proper safeguards. **Gas and Electric Light.**

Gas fittings and electric light work should be kept quite distinct from each other. **Gas fittings and electric work to be distinct from each other, etc.**

Gas fittings should never be used for the electric light unless permission to do so has first been obtained. The gas fittings would then have to be made thoroughly suitable for the purpose, and so arranged that it would be impossible for them to be the means of an "earth" setting up.

The utilization of gas fittings for the electric light may be the cause of the entire installation breaking down.

The insulation resistance between a gas fitting utilized and earth should never get below 2,000,000 ohms.

Accumulators. Batteries.

Accumulators, Batteries, etc.

No. 24. Where accumulators, or primary batteries are used, the mains, both positive and negative, must have a cut-out and switch upon each. The principal branches must also be protected in a similar manner. Small conductors taken off the mains must have cut-outs on both poles. Accumulators and batteries must be situated in a secure and approved place or room and where *there is thoroughly good ventilation*; they must be thoroughly well insulated from earth. All work (including wiring) in connection with them should be frequently examined.

Good Ventilation essential.

The conductors from the regulating cells of the accumulators to the regulating switchboard should be protected by "cut-outs."

Conductors and Wood casings.

All wood casing and conductors, etc., in the accumulator or battery room should be coated with an approved compound that will protect them as much as possible from the injurious action of acid fumes or spray.

No Lights to be in battery rooms where danger of explosions, without permission.

In any battery or accumulator room where the conditions are such that an explosion might occur from the gases given off, no light or electric lamp is to be used, except those for which special permission is given by the Fire Office. The electric work in such rooms must be of special character.

A full description of any battery intended to be used must be sent to the Fire Office—certain kinds of batteries are not allowed to be used without permission.

The current should be able to be turned off at the accumulators or as near as possible, whenever required, and the same applies to primary batteries.

The lug connections of accumulators should be periodically examined.

INTERNAL WIRING OF BUILDINGS

Concentric Wiring.

No. 25. Concentric conductors will be allowed under those circumstances and in those places for which permission has first been obtained and when the particular system, design, arrangement and materials to be used are approved by the Fire Office. All joints and connections must be so made that freedom from undue heating would be absolutely secured, and the outer conductor must be so securely protected that all danger from injury, corrosion, or other causes (electrical or otherwise) would be effectually prevented; the precautions taken must also be such that it would be impossible for the conductors to be affected by moisture. The whole of the work must be to the satisfaction of the Technical Adviser of the Fire Office. Concentric Wiring.

When the pressure of current does not exceed 250 volts the insulation resistance between the internal wire and the return of a concentric conductor before being placed up should not be less than 1,000 megohms per mile.

The internal wire should be positive, if possible. It must be insulated to the satisfaction of the Technical Adviser of the Fire Office, in accordance with Rule No. 3; the insulation must be impervious to moisture and of approved thickness. This insulation should have two approved metallic envelopes, the first one forming the return conductor, the second one forming the "guard"; these, except when the system is earthed, must be insulated from each other in the same manner that the internal wire and the return are insulated from each other. The "guard" must be an absolutely efficient protection against mechanical injury taking place to the return conductor, and also an efficient protection against any accession of moisture to the insulation, especially when the system is earthed.

The carrying capacity of the conductors must be at least equal to the ratio of that laid down for copper in Rule No. 1; if, however, a metal other than copper be used, the specific resistance of which is greater than that of copper, then the sectional areas of the conductors must be proportionally increased.

No metal, however, will be allowed to be used for the conductors or the "guard" that does not meet the approval of the Technical Adviser of the Fire Office; the thickness also

of the metallic envelopes forming the return and the "guard" must be to his satisfaction.

All switches and cut-outs must be enclosed in approved fire-proof boxes.

If the system is to be earthed, then the earthing must be efficiently and safely done to the satisfaction of the Technical Adviser of the Fire Office. An earth connection must never be made to a gas pipe, nor an hydraulic pipe, nor to lead or compo pipes, etc. ; nor to any other pipe, metal work, etc., the Technical Adviser objects to.

An earthed concentric system must be concentric throughout (that is an installation must not be partly concentric and partly not so).

Switches and cut-outs must always act on the internal (or live) wire when the system is earthed ; but switches and cut-outs may be required on the other wire, should the Technical Adviser of the Fire Office consider it advisable. If the current is derived from an outside source arrangements must be made, if in his opinion it be desirable, that both conductors can be simultaneously severed from the outside supply mains whenever required. The entire arrangement of switches and cut-outs must be to his satisfaction, and full particulars must be sent for his approval previous to the work being commenced.

The insulation resistance of the work when placed up must never be below that given in Rule No. 32 for general wiring.

When the system is earthed the test so far as earthing is concerned will of course refer to the pole that is not earthed.

TRANSFORMER SYSTEM (HIGH TENSION BUT NOT EXCEEDING 3,000 VOLTS).

Trans-formers and High Pressure Currents.

No. 26. No high tension work or secondary work in connection therewith is allowed in any risk or place that is objected to by the Fire Office.

Position of Transformers and High Tension work.

When transformers are employed, and the alternating primary current is of high electro-motive force, neither the transformer nor any portion of the primary work in connection therewith should be placed inside any building, but in an approved fireproof chamber apart. If this cannot conveniently be done, then the fireproof chamber may be placed in an approved position inside the building, preferably against an external wall, so that the primary conductors may enter direct and not traverse any portion of the

building. The fireproof chamber should be of brick or stone, and ventilate if possible into the open air.

The primary conductors must be most heavily insulated with specially prepared insulation of the highest quality and of lasting nature ; the composition thickness and electrical resistance (which must be very high) of the insulation must be to the satisfaction of the Fire Office ; the insulation must be waterproof, and have a very strong external covering. The conductors where they enter the transformer chamber (or run inside any other building for which permission has been given) must be enclosed in approved substantial casings, which must be waterproof and fireproof, and the arrangement must be such that no leakage of electricity could take place to earth from either of the conductors nor any short circuit from one to the other. **Primary Conductors.**

The primary conductors (unless concentric and one pole is earthed) must be each furnished with a switch, and these must be interlocked ; they must also each have a cut-out, which will act at or below 25 per cent. above the normal current. Should the conductors be concentric with one earthed then no cut-out is to be placed on the earthed conductor, and no switch, unless the Technical Adviser to the Fire Office (to whom full particulars must be sent) considers it necessary that arrangements be made so that every conductor can be *simultaneously* switched off from the outside supply whenever desirable ; the entire arrangement of switches, cut-outs, and the whole work must be to his satisfaction. The switches and cut-outs must be of an absolutely safe kind, and of such design and make that an arc in any of them could not be sustained ; they should be securely placed at the entrance of the primary conductors into the fireproof chamber. **Primary Switches and Cut-outs.**

When permission has been given for primary conductors to enter a building before reaching the **Primary Conductors inside a building.**

fireproof chamber, then the cut-outs and switches must be enclosed in approved fireproof boxes, and placed in accessible and secure positions outside the building, if possible. If they cannot be placed outside the building, then they must be situated in approved positions at the entrance of the primary conductors into the building. The position of all switches must be such as to be readily accessible, in order that the primary current can at once be turned off if required, and without any possibility of shock.

Safe placing of Primary Work.

The whole of the primary work within or upon any building should be so situated and arranged that it could not be tampered or interfered with by unauthorized persons, and the arrangement should be such, that if any portion heated or fired, no damage to the building or contents would result.

Too much attention cannot be bestowed with regard to the proper placing of all portions of the primary work, and rendering it safe and reliable.

Concentric Conductors.

Should it be desired to use concentric conductors, then samples of the same must be sent to the Fire Office for their approval when applying for permission.

Safety Devices.

A transformer should be so constructed that it would be impossible under any circumstances for the primary current to get into the secondary conductors. All secondary work must be protected by an approved automatic apparatus (or arrangement) at or near the transformer, so that in the event of the difference of potential between either secondary conductor and the earth unduly increasing at any time, the automatic apparatus would act and cut off the primary current before any danger of fire could arise.

Pressure of Primary Current.

Unless special permission be obtained, the primary current entering a house transformer must never exceed 3,000 volts. Should the current be generated higher than this, and reduced by means of transformers, then at each transformer, intermediate between the generator and the house transformer, there must be

such an arrangement, or approved automatic apparatus or device, whereby the pressure of the current conveyed by the conductors leading from the transformer, in the direction of the house or houses to be supplied with electricity, would be prevented from rising, under any circumstances, more than 10 per cent. above the normal. That is to say, supposing the current is generated at 10,000 volts, and converted down to 3,000 volts, then the mains carrying 3,000 volts could never be charged with electricity of a higher pressure than 3,300 volts.

Secondary Work. The secondary conductors must be highly insulated as before described in Rule No. 3; and they must be furnished with switches and cut-outs on both poles, except in the case of small circuits, when a single switch and double cut-outs can be used. The whole of the work should be of the very highest quality, and must be to the satisfaction of the Fire Office. The pressure of current in the secondary work must not exceed 250 volts without permission.

Earthing. When transformers, conductors, primary switches, primary cut-outs, etc., are enclosed in metal casings or metal boxes, etc., the casings or boxes, etc., must be efficiently and safely connected to earth.

An earthing wire must never be attached to, nor in contact with, a gas pipe, nor an hydraulic pipe, nor a lead or compo pipe, etc.; it must be kept at a perfectly safe distance therefrom; and also from any other pipe or metal work advisable, or considered so by the Fire Office.

General. Where the primary conductors enter or leave the switches, or enter the transformer, and it is not possible to keep them the above-mentioned distance apart, then a shorter distance may be allowed provided they are protected to the satisfaction of the Fire Office.

Where the secondary conductors pass out of the transformer house, they should do so separately, in approved earthenware or other fireproof tubes or casings. If, however, metal tubes or casings are used and the current is alternating then both conductors must be in the same tube or casing.

When transformers are to be arranged in series, permission must first be obtained. The alternation of safeguards necessary will be decided as each particular case arises.

"MULTIPLE SERIES" SYSTEM.

"Multiple Series" System.

No. 27. When the "multiple series" system is intended to be used in any building special permission must first be obtained before any work is commenced. A full description of the proposed work and safeguards to be adopted must be sent.

THREE (OR MORE) WIRE SYSTEM.

Three (or more) Wire System.

No. 28. Three (or more) wires with a pressure of over 250 volts between the outside ones are not allowed in a building, without the sanction of the Fire Office. The same of course applies if the three or more wires are brought into the premises in the form of two or more circuits, should there be a pressure of over 250 volts between any pair of terminals or conductors in a building.

By pair is meant *any two* terminals or *any two* conductors in the premises ; they need not necessarily belong to the same circuit, and may be far apart.

If the system has more than three wires the electromotive force of the current may have to be considered as depending upon the particular wires of the series brought in, and their relation to the outer ones of the series.

Three-Wire System.

When a building is supplied with current from a three-wire system, the electro-motive force of the current in the building may have to be considered from a fire point of view equivalent to that existing between the first and last conductors of the series, notwithstanding that two conductors only are brought into the building.

Thus in a three-wire system with 100 volts pressure between either outer conductor and the central one, the electro-motive force inside a building may have to be considered as equalling 200 volts from a fire point of view. If there be 250 volts between each outer conductor and the central one—the electromotive force may have to be considered as 500 volts.

The main switches on a three-wire system should be composed of two pairs of interlocked switches so arranged that the middle wire is cut twice. (If more than three wires be used the same principle must be followed—the switches always being in interlocked pairs.)

Arrangement of Main Switches.

The three main conductors should be taken to two separate incombustible distribution boards (the middle conductor dividing for this purpose into two), one for each side of the system and, if possible, at least ten feet apart, and from these boards the house two-wire circuits should be taken. Instead, however, of bringing in three main conductors into a building from a three-wire system, it is far better to bring in two circuits (one from each side of the system) at least ten feet apart, to incombustible distribution boards. When permission has been given to use a three-wire system with a pressure of over 125 volts between the neutral wire and either outer, no single floor should be wired from both sides of the system but from one side only. The floors should be wired alternately from each side of the system.

Arrangement of Main Conductors.

All conductors must be protected by cut-outs with the exception of the neutral (or middle) main.

Three-Phase System.

No. 29. There must be a switch on each of the three conductors, and the switches should be interlocked. There must also be a cut-out on each of the three conductors (except when considered unadvisable by the Technical Adviser to the Fire Office).

Three-Phase System.

With regard to a conductor from the neutral point: the description of the Three-Phase System and what is proposed to be done in a building sent to the Fire Office when applying for permission to use the system must state whether the neutral point is to be earthed in order that the Fire Office may determine the safeguards necessary.

Supply Mains (or Conductors) from a Central Station and Consumer's Premises.

Supply Mains or Conductors from a Central Station and Consumer's Premises.

No. 30. When electricity is sent from a central station, each main or conductor therefrom must have a cut-out and switch at its point of entrance into the premises supplied with current, and (as stated in Rule No. 15) the mains, etc., must be brought into the building in as perfectly secure a manner as possible to points suitable for placing up these cut-outs and switches in thoroughly safe and accessible positions. It is impossible to over-rate the importance of taking all known precautions with regard to the prevention of fire when placing in the supply mains or conductors, and coupling them up to the house wiring. The cut-outs should act at as small an excess of current above the normal current as is compatible with the proper and efficient working of the lights—the excess above the normal current should never exceed 50 per cent., unless permission to the contrary is given. The switches and cut-outs and conductors should be effectually protected against any possibility of moisture getting to them.

Precautions to be taken to prevent fire entering premises from outside mains, etc.

The supply mains or conductors must be brought into the premises in such a secure manner and with such precautions, that if a fire arose in the electrical mains or work outside the premises, it would be prevented as far as possible from entering the building.

Supply mains or conductors entering and also inside premises should be in substantial iron barrel (unless the conditions are such that it would not be well to use it), and the cut-outs and switches enclosed in substantial iron boxes.

Cut-outs may be placed on the conductors supplying current to the building in a service box outside the premises instead of at the points of entrance.

Earthed System.

If one pole of a supply system be "earthed," each conductor must still have a switch at its point of entrance into the consumer's premises. The switches must be interlocked, and care must be taken that they are always in perfect order.

3-wire System.

If a 3-wire system is used the work must accord with Rule No. 28.

Where the supply mains or conductors are brought into a warehouse or buildings of like nature containng great quantities of inflammable goods, or when they are brought into very special risks, the supply mains, main switches, main cut-outs, and meter, etc., should be all enclosed in a fireproof chamber, out of which the conductors for the lighting, etc., should pass in an approved fireproof tube or tubes.

Mains, Main Switches, and Cut-outs and Meter to be in fireproof chamber in certain risks.

The occupier must be able to turn off the electricity entirely from his premises whenever he considers it necessary. The switches should be of quick and wide break type, and they must be so arranged that they will always act together.

Consumer must be able to turn off the Electricity entirely from his premises.

Central Stations and Accumulators.

No. 31. When currents of 200 volts or over are used from a central station (or other place) to charge accumulators, and secondary house circuits having a current of lower potential than that of the current from the central station are taken from the accumulators, then the conductors for the house circuits should be provided with a device or arrangement by means of which their connection would be severed with the accumulators during the time these latter were being charged.

Central Stations and Accumulators

Tests.

No. 32. In any electric light installation in which the current is continuous and has an electro-motive force of 250 volts or under, the insulation resistance with regard to earth over the whole installation must never get below the following :—

Tests.

Installations of	12	Lights	..	1,600,000	Ohms.
"	25	"	..	800,000	"
"	50	"	..	400,000	"
"	100	"	..	200,000	"
"	400	"	..	50,000	"

When the lights are proportionate between the above number, then the insulation resistance should be correspondingly proportionate.

The insulation resistance between conductors with all apparatus and fittings connected (except lamps) must also be taken, and should never be less than the above table.

The insulation resistance of the separate circuits (or branches) of an installation should be taken, and the resistance should never be below that stated in the above table; for instance, if the circuit contains 12 lights, then its insulation resistance shall not be less than 1,600,000 ohms, and so on.

The minimum insulation resistance when the currents are of greater pressure than 250 volts will be decided with regard to each instance as it arises, so much depending upon the particular circumstances of the case.

For alternating currents of similar electro-motive force the insulation resistance should not get below twice the number of ohms given in the above table.

Under normal conditions the fall of potential in the conductors in a building should not exceed 2 per cent. at the farthest point in any circuit when all the lamps are alight.

Under certain circumstances the Technical Adviser of the Fire Office may give permission for the insulation resistance to be less than that contained in the before-mentioned table.

A statement of the insulation tests must be supplied if required.

All tests should be regularly entered in a book kept for the purpose.

An isolated installation should contain an automatic device that would give a warning if a leak were set up to earth. (This recommendation would also apply to a non-isolated installation if the circumstances of the same rendered the use of such a device advisable.)

The pressure of the testing current should be, at least, equal to that at which the current is to be used.

No. 33. When electricity is supplied from a "central station" to one or more buildings, accurate insulation tests should be made at least once daily over the whole system; and a record be kept of the same. Too much attention cannot be bestowed to this matter, especially where transformers are employed, or when the "multiple series" system is used.

Central Station Tests.

LIGHTNING PROTECTION AND EXTERNAL CONDUCTORS.

No. 34. External conductors entering, or connected to, or traversing any building or buildings, should, where necessary, have an arrangement of lightning arresters (thoroughly well placed up in secure positions outside the building or buildings) that would effectually prevent the said conductors being a means whereby lightning could strike or enter the building or buildings.

External Conductors to have Lightning Arresters.

WAREHOUSES, DRAPERS' SHOPS, CHURCHES, ETC.

No. 35. Special precautions may be required to be taken with regard to electrical work in warehouses, drapers' shops, and similar risks. No work should be commenced or done without first consulting the Fire Office and learning what precautions it considers necessary under the particular circumstances of the case.

Electrical work in Warehouses and Drapers' Shops, etc.

In these risks the greatest care must be exercised not only to keep the lamps, but all switch boards, switches and cut-outs, at a safe distance from all combustible materials and goods. Too much attention cannot be given with regard to fixing up the work securely, and the utmost care should be taken to render it impossible for goods to come into contact with incandescent lamps, fittings or conductors; in some cases it may be necessary to enclose the incandescent lamps in glass globes. No arc lamps to be in any place or position that may be deemed

undesirable by the Technical Adviser of the Fire Office. All arc lamps should be double enclosed. No portable lights on flexible conductors should be placed in the shop windows or shops, or where there are inflammable goods.

No switch board or cut-out board, etc., should be on wood fittings, wood-work, or on match-boarded walls, etc. : they should be properly placed on a brick or stone wall. No switches or cut-outs should be on wood fittings, etc., containing goods.

The greatest care should be taken that the supply mains are brought into a perfectly secure part of the premises—not into a shop window or in the shop itself, or in the vicinity of goods—and the arrangement should be such that the current could be turned off any portion of the premises at any time.

The conductors in the above class of risks should be in approved iron barrel when it can be used.

Churches.

Installations in churches should be most carefully done. No work should be in the roof if possible. Any conductors about the organ should be in welded iron barrel or other approved metal tubes, and the switches and cut-outs in iron boxes. No flexible wire should be used at the organ. Should an electric motor be used it must be situated in a secure place and be in a fireproof compartment or case.

CENTRAL STATIONS, THEATRES, MILLS, AND VERY HAZARDOUS RISKS.

Very Hazardous Risks.

No. 36. In very hazardous risks, special precautions may have to be taken, such precautions necessarily varying according to the peculiarity of the circumstances of the hazard.

Central Stations.

With regard to central stations the buildings should be fireproof, of one storey construction, lofty and dry. They should never be crowded up, but contain ample space for the machinery, apparatus, switch boards,

etc., with plenty of room for the work-people to move about in. All conductors should be most carefully arranged and protected, and be in iron pipes where convenient and practicable; bunching should be most carefully avoided. If the roof is boarded under or contains any woodwork, all conductors should be kept as far as possible from it; disastrous fires having been caused by lack of this precaution. It would be far safer if the roof contained no boarding or combustible material whatever. Central stations should contain no match-boarding. The switch boards must be fireproof, and so placed that there would be ample room for a man to work securely, safely and comfortably behind them or in front of them at any time. The positive and negative conductors should be on separate boards where practicable. The work should be on the front of the boards as far as practicable; no apparatus should be on the back or in the space behind the boards, which should be kept perfectly clear; the conductors at the back of the boards should be most carefully spaced out, and securely arranged (the positives being kept well apart from the negatives when for the same board). Special care should be taken to ensure that all fastenings and connections are always in perfect order.

The surroundings of the switch boards should be fireproof, the aim being that if a fire broke out on a switch board it could not extend beyond, or would have difficulty in doing so.

The conductors might be brought well apart to the switch board by means of a tunnel or a channel in the fireproof floor, the tunnel or channel should be fireproof and contain no other apparatus, and where the conductors go through the floor, to or from the tunnel, arrangements should be made so that fire would have difficulty in travelling along them. It would be better if the insulated conductors in the

channel or tunnel were in iron pipes where practicable.

The temperature of the station should be kept as low as possible ; this is of great importance.

Too much stress cannot be laid upon keeping the station clean, cool, well ventilated, in thorough repair, and absolutely impervious to moisture.

Fire buckets containing dry sand should be kept in the station at places where they would be easily and quickly accessible.

Theatres.

With regard to theatres, the work should be of a special character—the work in connection with batten, wing and float lights should be incombustible, the switch boards and distribution boards should be incombustible, with a brick or stone wall behind, and no combustible materials in the vicinity, and the boards should be situated and arranged with the view of the minimum possibility of a fire extending if it broke out upon any of them. The work in connection with floor plugs or temporary attachments must be fireproof and special, great care being taken to prevent any liability of heating being set up from bad contacts or other causes ; fixed conductors, especially on the stage, should be in iron or steel tubes, or in specially approved casings ; any loose conductors should have very strong coverings to their insulation ; all lights must be at a safe distance from all combustible materials. All arc lights must be securely enclosed and situated ; special care must be taken with regard to the safe placing of resistances, which must be in approved iron boxes on brick or stone walls. If liquid resistances are employed they must be most securely arranged and situated, and have thoroughly good ventilation.

If arc light are to be used on the stage, permission must first be obtained.

All work should be "surface" and specially protected against liability to injury.

The wiring should be arranged in circuits, as small

as could conveniently be employed, with double switches and double cut-outs to each. No work to be inside any roof.

Paper Mills. **Bleach Works.** In paper mills, the greatest precautions must be taken against damp and corrosive vapours or gases. The same applies to bleach works.

Sugar Mills. In sugar mills, special precautions have to be taken to prevent deleterious action from the high temperature, and in some instances from corrosive action. In some places it may not be advisable to place up electrical work.

Saw Mills. In saw mills, great care must be taken, especially with regard to keeping all work free from injury, and also the lamps, holders, roses, cut-outs, resistances, switches, switch boards, etc., free from fine dust, and placing the same in secure positions; the work should be of the highest class throughout, and arranged in small circuits with double switches and double cut-outs to each. No flexible wire should be used in the working rooms—all lights there should be fixed, and in some places it may be necessary to enclose the incandescent lamps in glass globes. Approved metal tubing should be used to carry the conductors, special care being taken that double switches are provided for each room. **Cotton Mills.** **Corn Mills.** The same recommendations also apply to cotton mills and corn mills; here the dust or fly given off is more inflammable.

Breweries. In breweries, much precaution is requisite with regard to security, especially as the work is liable to the action of damp, acetic acid, etc.

Printing Works. In printing works, great care has to be taken with regard to safety, and especially to prevent the work getting mechanically injured.

Naphtha and certain Chemicals. Again, in risks where naphtha or certain chemicals are used, or injurious products are given off, a solvent action may be set up on the insulation, or the chemicals employed or products given off, may act injuriously upon the electrical work and slowly or quickly eat it

away; the conditions might be such that it would not be advisable to place up any electrical work.

No rules can be drawn up to govern all cases.

Hazardous risks vary so greatly that it is impossible to lay down hard and fast rules that shall govern all cases, without being unnecessarily stringent in some instances and unduly lax in others; each risk really requires to be separately considered with regard to its own special characteristics; no electrical work therefore should be placed up in such risks without previously consulting the Fire Office.

Fire Office should be consulted.

Electrical Power Installations, Electrical Machinery and Apparatus.

Electrical Power Installations.

Situation of Electrical Machinery.

No. 37. No motor, dynamo, transformer, or any apparatus for generating or altering electricity, either for lighting or power, etc., to be placed in any room except the engine room (or other approved room), in any cotton, woollen, lace, flax, jute, corn, oil, saw-mill, etc., or in any mill or factory of a like description, or in any room, or place, where any hazardous manufacture or process is carried on, or in which hazardous goods are stored, or where there is risk, without certain special precautions being taken with regard to safety, unless permission to the contrary be given by the Fire Office.

Fireproof Compartments for Motors, etc.

Electro motors and dynamos, when in buildings such as above described and not situated in the engine-room (or other approved room) must be placed in an approved fireproof compartment, so that if the motor, etc., fired, the fire could not spread; and provision must be made that no fine dust, "fly," waste, etc., could get in, hence the compartment should not ventilate into the building but into the outside air, and the only apertures in the walls of the compartment into the building should be just sufficient for the shafting and the conductors to separately pass through, the latter being most carefully protected in

doing so. The door should be of iron or other approved fire-resisting material. The pulley should be external, but the resistances, etc., if not in the engine-room, should be placed inside the above compartment.

If, however, it would not be convenient to ventilate the above compartment into the open air, then the compartment may have ventilating apertures in its vertical portion, each of such apertures being properly covered and protected by two layers of approved metal gauze not less than $\frac{1}{4}$ inch apart; unless in the opinion of the Fire Office such or any apertures would not be desirable.

Metal Cases for Motors, etc.

With regard to enclosing motors, etc., in metal cases instead of placing them in fireproof compartments, a metal case should not be employed if its use would cause the motor to unduly heat, or be a source of danger through persons being liable to get shocks from it.

When cases are used they should be of substantial metal, the arrangements for ventilation must be the same as those above described for fireproof compartments, namely, either by apertures in the vertical portions of the case (unless apertures be considered undesirable by the Fire Office) covered by two layers of approved metal gauze not less than $\frac{1}{4}$ inch apart—or else into the open air—and the case must contain no other openings except those just sufficient to allow the shafting and the conductors to pass through; the apertures for these conductors must be bushed with insulating material. The pulley must be external.

Induction Motors, openings in their cases, etc.

Induction motors may (unless in those instances considered undesirable by the Fire Office) have unprotected ventilation openings in their metal cases provided the superficial area of each opening does not exceed $\frac{1}{4}$ of an inch, and the openings being at least $\frac{1}{4}$ of an inch apart, but the total area of the openings must not exceed one half that of the superficial area of the case without permission. Slip rings

and brushes or any other sliding contacts must be completely enclosed in metal cases. There must be no exposed terminals.

Resistances.

The resistances, etc., when not in a fireproof compartment must be enclosed in a substantial iron box (or other approved fireproof material), and if ventilation be required it must be on the principle described on page 207 for fireproof compartments and metal cases; the resistances must be efficiently insulated from the metal of the box.

The resistance box must be on a brick or stone wall, and at a perfectly safe distance from all combustible material.

Impossible to draw up hard and fast rules to apply to all Risks, conditions vary so greatly.

It must, however, be remembered that the fire risk of buildings and the conditions met with vary so greatly that it is quite impossible to draw up hard and fast rules that shall apply to all. In some buildings it may be necessary to carry out the whole of the above precautions; in others it may not be necessary to enclose the motors at all, therefore when motors, etc., are to be placed up in buildings, inquiries should be made of the Fire Office as to the proper precautions requisite.

Wood Floor under Motors and Dynamos to be protected, etc.

Wood-work and combustible materials to be at safe distance away.

No motor or dynamo should be on a wood floor in any building, unless the wood floor under is protected by fireproof material to the satisfaction of the Technical Adviser of the Fire Office. All wood-work, both vertically and horizontally, must be at an absolutely safe distance away—or the wood-work efficiently protected with fireproof materials to the satisfaction of the Fire Office. All combustible materials must also be at a safe distance away.

Motors to have separate Circuits.

Each motor should be on a separate circuit.

The arrangements with regard to each motor should be such that the current could be entirely disconnected by switches from both poles of the motor and conductors in connection therewith, when the motor is not in use.

Motors should be furnished with approved automatic cut-offs of such design and arrangement that if the current failed, or the motor became unduly overloaded, the motor circuit would be automatically broken, and the motor could not be started again until after the resistance switch had automatically been brought to zero. **Automatic Cut-offs, etc.**

A motor should also be provided with an apparatus of such a nature that the maximum working current would be automatically prevented from being exceeded.

All metal cases, boxes, tubing, etc., and the frame of motors and dynamos must be efficiently connected to earth (except in any special instance objected to, or considered unnecessary by the Fire Office). **Earthing.**

When motors not enclosed in a fireproof compartment or metal case are allowed, care must be exercised that they are placed in thoroughly secure situations, and so arranged that if on fire, the fire would be prevented as far as possible from spreading; the resistances must be enclosed in a metal or other approved fireproof case or box, and with all other apparatus be securely arranged and placed to the satisfaction of the Technical Adviser of the Fire Office. **Motors not in fireproof compartments or metal cases.**

With regard to very small motors for fans, etc., the question as to whether they should be enclosed or not, and the distance that woodwork should be kept from them, will depend upon the size and kind of motor, nature of risk, etc.; so much depending upon the circumstances of the case. **Fan Motors.**

An electrical power installation requires at least the same wiring safeguards that apply to an electric light installation, in which the conditions of supply and the electro-motive force of the current are similar. The insulation of the conductors must be in accordance with Rule No. 3. **Wiring Safeguards.**

When the pressure of current used is between 150 volts and 500 volts the conductors must be enclosed **Electrical Power.**

Installations when pressure between 150 volts and 500 volts.

in approved welded, or solid drawn iron or steel tubes with screw joints, and electrically continuous, the switches, cut-outs and resistances must be in approved fireproof boxes, or cases, and thoroughly insulated therefrom. When alternating currents are used both conductors must be in one tube. The insulation resistance of the conductors before being placed up should not be less than 2,000 megohms per mile; or 2,500 megohms per mile if the pressure is 400 volts, or between that and 500 volts. The whole work must be of the most safe and secure description.

Insulation Resistance.

In any electrical power installation in which the pressure of the current does not exceed 500 volts, the insulation resistance to earth of each motor, together with its resistances, switches, cut-outs, conductors and accessories, should never get below 1,000,000 ohms. The insulation resistance between conductors with all fittings and apparatus connected (except motors) should not get below 1,500,000 ohms.

The minimum insulation resistance when the currents are of greater pressure than 500 volts will be decided with regard to each particular case as it arises.

Electrical Power Installations—(*contd.*)

Trolley Wires and Motors (Direct Current).

No. 38. No motor is allowed to receive current from any tramway (or railway) trolley wire with an earth return, unless special permission has been obtained from the Fire Office.

Conductors

When such permission has been obtained, it may be mentioned that the insulation resistance of the conductors before being placed up inside the building, must not be less than 2,500 megohms per mile for currents not exceeding 550 volts pressure. The conductors must be enclosed in substantial iron or steel tubing, welded or solid drawn, with thoroughly well screwed joints—metal to metal. This tubing must be screwed into a cast-iron terminal box forming

Metal Tubing, Switches, Cut-Out Metal Boxes, etc.

part of the motor framework. The conductors must have an efficient switch on each pole at their entrance into the building, the switches being interlocked so as always to act together. The positive or live conductor must have an efficient cut-out at its entrance into the building. The switches must be in a cast-iron box, and the cut-out in a separate cast-iron box, and into the boxes the iron tubing must be screwed; the insides of the boxes must be lined with an approved insulating incombustible material: or the switches and cut-out could be in boxes composed of approved fireproof insulating material, enclosed in cast-iron boxes. The switches, cut-out, and boxes, must be of thoroughly safe kind in every way, and in secure positions. The whole of the metal tubing and the metal boxes to be electrically and mechanically continuous. The motor must be furnished with an approved automatic cut-off of such design and arrangement that if the current failed, or the motor became unduly overloaded, the motor circuit would be automatically broken, and the motor could not be started again until after the resistance switch had automatically been brought to zero. The motor must also be provided with an efficient apparatus that would automatically and effectually prevent the motor receiving any current at a greater pressure than the motor was designed and proved to easily and safely bear. The cut-offs and apparatus must be enclosed in approved iron boxes, which must be electrically continuous with the iron tubing, etc.

Automatic Cut-offs, etc.

Earthing.

All metal tubing, metal boxes, cases, etc., and the frame and shaft of the motor, must be thoroughly well and safely earthed.

Lightning Arrester.

The positive or live conductor must have an efficient lightning arrester in an incombustible box placed in a secure position outside the building. The earthing arrangements must be most carefully and efficiently made.

Return Conductor.

The return conductor to have no cut-out, and must be thoroughly well bonded to the tramway rail, and most carefully protected against any possibility of injury. It should be carried back to the tramway rail in iron barrel, which should also be bonded to the tramway rail. Efficient precautions must be taken to prevent any possibility of electrolysis occurring.

Separate Circuit for each Motor.

Each motor must be on a separate circuit.

Care with regard to work.

All work must be most securely and carefully placed up, due regard being taken of the pressure of the current to be used, that an earth return will be employed, and also that an increase of current above the normal might at times occur.

Work that is not specifically mentioned.

Any work or apparatus not herewith specifically mentioned must be provided with the same general safeguards as above mentioned, so far as they apply.

Full particulars of what is proposed to be done to be furnished.

When applying for permission to drive a motor by current from a tramway (or railway) trolley wire, a full description must be furnished of what is proposed to be done, including the kind of motor to be employed, its electrical horse-power, the normal pressure of the current, the maximum possible excess, and the safeguards to be adopted. A sufficient description of the electrical system and arrangements of the tramway must also be sent. The Fire Office will then be able to decide, if granting permission, whether further requirements than those contained in Rules No. 37 and No. 38 would be necessary, or whether some of them could be modified or dispensed with.

When alternating currents are used both conductors must be in the same metal tube.

Electrical Cranes.

Electrical Cranes.

No. 39. The risks and circumstances in which electrical cranes are used vary so greatly that it is impossible to draw up rules that shall apply to all cases. When therefore electrical cranes are proposed

to be used full particulars of the work and the safeguards should be sent to the Fire Office for approval.

The particulars must contain a description of the motor and general electrical arrangements including the wiring, and clearly state how the motors are to be enclosed, whether any bare conductors are absolutely necessary, and if so, their proposed situation, length, method of fixing, etc., etc.

It may be mentioned that any bare conductors must be most securely and rigidly fixed to approved porcelain or earthenware insulators. The conductors must be at least 6 inches from each other, from other metal or wood-work, and from the side of the gantry or other structure they are supported by.

Efficient precautions must be taken against any possibility of leakage of current from the conductors, and from combustible or other materials coming into contact with them.

The whole work must meet the approval of the Fire Office.

Electrical Heating.

Electrical Heating (general).

No. 40. When any building or portion of a building is to be heated by electricity, or electric heating is used for other purposes, notice must be given to the Fire Office; the system and arrangements must be such as meet their approval, and no electrical heating or arrangements will be allowed in any building or in any part of a building that does not meet with their sanction.

The same general electrical safeguards and arrangements must be taken with regard to the installation as are required by these rules for an electric light installation, so far as they apply, but with the addition of such other safeguards as are stated here, or may be considered requisite by the Fire Office.

Radiators or Stoves, etc. Safeguards and safe placing.

The same general safeguards for security from fire and heat will be required with regard to electrical radiators or electric stoves that would be considered necessary by the Fire Office, if the radiators or stoves, instead of being heated by electricity, were heated by other means. They must be considered in certain respects as fire-heated stoves. Arrangements must be made so that the temperature of the radiators will not exceed that for which permission is given.

All radiators or stoves must be fixed at such safe distance from wood-work and all other combustible substances as may be required.

No radiator or stove to be fixed in roofs, cupboards, nor in any position or place that may be objected to.

Every radiator or stove should be protected by its own separate cut-outs and have double switches.

All radiators should be fixed to, or stand upon, approved fireproof insulators.

Sockets and Plugs.

All sockets and plugs should be incombustible: they must be to the approval of the Fire Office. No sockets will be allowed in any place nor in any risk that may be considered undesirable.

Floor-sockets are not allowed (unless previous written permission has been obtained). If permission to use them be given, they must be efficiently protected against mechanical injury, and from damp, and other injurious influences.

Every socket should be so constructed that the contacts are automatically covered when the plug is removed.

Conductors, etc.

The conductors for supplying current to the radiators must be attached to proper terminals of large carrying capacity. They should, if possible, be brought to the radiators or stoves in approved iron barrel or approved armoured tubing.

The mains and all principal branches must have a switch and cut-out on each conductor. [If the system is a 3-wire one then no cut-out is to be on the neutral (or middle) main].

No conductor to be unencased without permission. The insulation upon any unencased conductor must be of special character, and have very strong coverings.

No conductor or any part of the work to be so placed that it will be exposed to mechanical injury.

No conductors to be so placed that they can be exposed to undue heat. The insulation of the conductors at the radiators should be special, and of fireproof character if necessary. The conductors should be enclosed in iron at their junction with the radiators or stoves.

Work and Materials, etc.

All work and materials to be of the highest character and to the satisfaction of the Technical Adviser of the Fire Office. The entire installation (including the insulation resistance of the whole work, both with regard to earth and between conductors) must be to his satisfaction.

Electric Heating in Hazardous Risks.

With regard to hazardous risks other special precautions may be required ; these, of course, may vary according to the nature and circumstances of the particular risk.

An electric heating installation should be distinct from any electric light installation or electric power installation that may be on the premises, unless permission be given to the contrary.

Insulation Resistance.

In any electrical heating installation, when the pressure of the current does not exceed 250 volts, the insulation resistance, with regard to earth of each heater, stove, radiator, etc., together with its conductors, switches, cut-outs, plugs, etc., etc., should never get below 1,000,000 ohms.

The insulation resistance between conductors with all apparatus and fittings (except stoves, radiators, etc.) connected, must not get below 1,000,000 ohms.

Any electrical apparatus used for giving off or diffusing heat will come under the head of radiator or stove.

Electrical Cooking.

Electrical Cooking (general).

No. 41. The same general rules must be observed as for electric heating, so far as they apply.

Every oven, stove, or other apparatus, should be protected by its own separate cut-outs and switches.

Wiring, etc.

The greatest care must be exercised in so arranging the conductors that there would be no possibility of any of them becoming unduly heated, either by proximity to or contact with any of the apparatus, or from other causes. Care must also be taken that none of the electrical work would be liable to mechanical injury.

The conductors should be enclosed in approved iron barrel or approved iron casing.

The insulation of the conductors at or near the oven, stove or other apparatus, may have to be special and of fireproof character.

Insulation Resistance.

The insulation resistance of the installation must be at least the same as that for an electrical heating installation, an electrical oven being considered as equivalent to a radiator or stove for this purpose.

General Safeguards.

With regard to the cooking apparatus the same general safeguards must be taken with regard to security from danger of fire that would be considered necessary by the Fire Office if the apparatus were heated to similar temperatures by other means ; and this applies also to the positions of the apparatus, methods of fixing, distance from and protection of woodwork or other combustible materials, etc.

The whole of the work to be to the satisfaction of the Fire Office.

Earth Return.

Earth Return.

No. 42. No earth return allowed.

Unless in those cases for which special permission has been given.

Telephone Wires, etc.

No. 43. Every telephone wire from an overhead system should have an efficient lightning arrester fixed in a thoroughly secure place outside the building containing the telephone, and near the entrance of the telephone wire. When, however, the telephone system is a complete underground one, and efficiently protected against lightning at the exchange, then no lightning arrester need be placed up on the wires entering the building, unless required by the Technical Adviser of the Fire Office. **Telephone Wires.**

Telephone wires must be so arranged and fixed that there would be no possibility of their coming into contact with any other conductor carrying current.

Earthing. Every telephone circuit that has not complete metallic return should be securely and efficiently earthed outside the building containing the telephone.

No circuit to be earthed to a gas-pipe.

All telephone wires inside buildings should be of copper and efficiently insulated.

Minimum Section. No telephone wire should be of less section than No. 20 S.W.G.

Insulation Resistance. The insulation resistance of a telephone circuit inside a building should never drop below 1 megohm.

Safeguards to be adopted. When the circumstances are such that a telephone wire might, through accident or other causes, come into contact with, or into dangerous proximity to, another conductor carrying current (for lighting, power, or other purpose) of such a pressure, that fire or danger might result from such contact or dangerous proximity, etc., then the telephone wire must be furnished with an automatic apparatus of such design, make and arrangement, that, if the pressure of the current in the telephone wire should exceed 50 per cent. of the normal pressure, the apparatus would

instantly act, and cause the current to be harmlessly conveyed to earth.

A cut-out also must be placed upon each telephone wire, in a safe place, as near to its point of entrance into the building as possible, and the cut-out must be of such a nature, that if the current should reach one-third of an ampère, then the cut-out would instantly fuse and cut the current off the building.

Outside telephone wires must be efficiently fixed at least four inches from the structure. They should be attached to approved insulators. Special precautions may be required when the buildings are of a very hazardous nature or when the circumstances of the case, in the opinion of the Fire Office, warrant them.

General.

The fixing of all telephone works, wires, apparatus, etc., both inside and outside a building, must be to the satisfaction of the Technical Adviser of the Fire Office.

Telegraph Wires.

Telegraph wires will come under the above regulations so far as they apply.

Trolley Wires.

Trolley Wires.

No. 44. Trolley wires passing under wires carrying current to a building for lighting, power heating, telephones or other purposes, must be efficiently guarded in such a manner that if any of the wires above them broke or sagged they would be prevented from coming into contact with, or dangerous proximity to, the trolley wires. Each wire over a trolley wire must have at its entrance into any building a safety device of such a nature that if the pressure of current in the wire exceeded at any time 50 per cent. of the normal pressure, then the device would instantly act and cut off the current from the building.

Character of all Electrical Work.

No. 45. All work and materials to be of the best character; and the installation to be accurately tested at the time of erection for insulation. Character of work.

All installations should be periodically examined and tested.

All Work Must be to the Satisfaction of the Fire Office.

No. 46. No departure from any of these Rules will be allowed without the sanction of the Technical Adviser of the Fire Office. The whole of the arrangement, machinery, work, fittings, materials, and safeguards, of the electrical installation must be to his entire satisfaction.

It is however quite understood that as Risks vary so greatly, it is impossible in fairness both to the Assured and the Fire Office, to lay down hard and fast rules that shall be imperative in every case under all circumstances. Therefore should difficulties arise, due to special conditions and circumstances of a Risk, with regard to carrying out any of these Rules, the matter must be referred to the Fire Office for their advice and decision.

MUSGRAVE HEAPHY, C.E.,
Member Institute Electrical Engineers, Etc., Etc.

INTERNAL WIRING OF BUILDINGS

ELECTRICAL FIRE RISKS

USEFUL FACTS TO BE REMEMBERED.

Electricity can readily change to fire.

Any portion of an electrical installation improperly placed up can self-fire, from the dynamo to the lamp; the parts hidden away being often the most dangerous; the incandescent lamp itself can set fire to combustible materials if it be in contact with them, and has been the cause of fires.

If the passage of electricity be retarded in any part of its circuit, the current of electricity develops heat.

Conductors of a certain diameter can only transmit a definite quantity of electricity safely (for a rough comparison, electricity going along a conductor may be likened to steam or water passing through a pipe); any amount above that may cause them to become dangerously heated. Conductors from this cause have got red, and even white hot; burning their insulating coverings, and setting fire to everything combustible they were in contact with.

If a positive and a negative conductor [1] are placed too near each other, and the insulating material of the conductors happens to get rubbed or worn off, an "arc" may be set up, and fire ensue. Hence the importance of keeping conductors well apart. Fires will arise if a "short circuit" takes place; that is if the electricity manages to get from one conductor to the other (which it is always anxious to do), without passing through the lamps, etc. Anything combustible that the electricity "short circuits" across may be set on fire. Hence the necessity of good insulation to the conductors.

A fire may break out if leakage of electricity takes place to "earth." Hence, again, the importance of good insulation, and of keeping conductors free from metal work, such as gas and water pipes, etc.

Moisture will "short circuit" or will "earth" conductors, and has been the cause of fires, some of which have arisen from washing floors when the conductors have been under.

[1] Or, in fact, any two conductors in which the electro-motive force of the electricity is different.

Hence the necessity of waterproof insulation to conductors when situated in damp places, or where any moisture can reach them; and also the necessity of care when fixing the positions of switches, cut-outs, and other parts of an electrical installation.

A fire may occur from loose connections or from bad joints—hence the necessity of good workmanship.

There is as much danger from an incandescent installation as there is from an "arc" installation, if either be not properly put up.

In fixing the position of a dynamo or motor, it must be remembered that many instances have occurred of dynamos and motors setting themselves on fire.

Switches are extremely liable to set up a fire if they get out of order, or are improperly constructed, or not properly fixed.

In laying out installations do not place too great reliance on "cut-outs," but trust to the manner the whole work has been arranged with regard to safety. Experience proves that "cut-outs," invaluable as they are, are no sure protection against an electric fire breaking our under certain circumstances. They have even themselves been the cause of fires occurring.

Although it is necessary to have tests taken of an electrical installation, it is an error to suppose that if they show good results they must prove the installation to be a good one and safe. Under certain circumstances it is possible for the tests to be very high and yet the electrical work may have been scamped and the installation be dangerous.

Trust first to the manner in which the whole work has been placed up, and next to the tests.

If you switch out your lights with a switch that acts on one conductor only, remember that this does not turn the electricity off, it is still practically in the conductors, and a fire can break out under certain circumstances (perhaps in the middle of the night) though not a single light is burning. Turn off your lights therefore by switches that act on both conductors, and so cut the current off entirely.

If your lights are burning dimly, and your electrical machinery is going at its normal speed, then leakage of electricity may be taking place, and an examination should at once be made.

When an electrical fire breaks out, turn off the current from both poles at the nearest switches, then use your appliances; the injudicious use of water without these precautions might increase the extent of the fire or perhaps be a source of personal danger.

MUSGRAVE HEAPHY, C.E.,
Member Institute Electrical Engineers, Etc., Etc.

NOTE.

If you put up electrical work to tender, remember this: *that any firm by arranging to place inferior quality of work in your premises can easily underprice other firms that are more conscientious;* and experience proves that *inferior work may result in a fire breaking out sooner or later*—perhaps between floors and ceilings, behind wainsscoting, or inside roofs. Be careful, therefore, previous to accepting a low tender, to make yourself certain that the *same quality* of work has been estimated for and intended to be done, as that of the higher tender.

Keep your installation in such a condition that it would be affected as little as possible by any leakage to earth from the company's mains that supply the current.

Be sure that all conductors and fittings are kept in good order, and that no connection gets loose or imperfect.

The electric light is, in the opinion of the Phœnix Fire Office, the safest of all illuminants, and preferable to any other, when the installation has been thoroughly well put up to its satisfaction, and the particular system employed has its approval.

The electric light must not be used in place where other illuminants are not allowed, unless special permission to do so has been obtained from the Fire Office. There are

also certain risks in which the electric light must not be used without special permission from the Fire Office. This also applies to electric power, electric heating, etc.

Before an electrical installation is used notice should be sent to the Fire Office, in order that an opportunity may be given for the installation to be inspected with regard to its Fire risk.

Full particulars of a proposed installation should be supplied before the installation is commenced.

Should an electrical installation be proposed to be altered, or the supply of current changed, or the pressure of current proposed to be raised or lowered, notice should be sent to the Fire Office. An electrical installation may be in a very safe condition, and yet, if altered (especially for purposes or conditions it was not originally arranged for), become very dangerous with regard to fire.

Users of electricity should never forget that an electrical installation requires to be periodically examined by a competent electrician, and attended to if necessary ; and at least every seven years the installation should be thoroughly overhauled, and brought as far as possible up to date with regard to safety requirements.

These rules, except where otherwise stated, are for installations using current at not over 250 volts pressure—the supply being from two conductors.

No earth return is allowed (except in those cases for which special permission has been given).

Should the assured's electrician have any doubt with regard to any matter contained in these Rules, or should there arise any difficulty from the particular circumstances of the Risk as to carrying out any of the Rules, he should communicate with the Fire Office for advice.

THE WESTMINSTER ELECTRIC SUPPLY CORPORATION, LIMITED.

INSTALLATION WORK RULES.

Caution.

The Corporation issue the following general information and rules for the guidance and assistance of consumers and those engaged in electric installation work. It must, however, be distinctly understood that the Corporation have no responsibility whatever for the work done by contractors on consumers' premises, and are in no way responsible for any loss or damage which may be occasioned by fire or by any accident arising from the state of the wires or fittings in the interior of buildings. The passing of an installation by the Corporation's Inspector simply means that it complies with the rules here laid down as to insulation tests. The Corporation take no responsibility whatever in respect of testing a consumer's installation on his own behalf.

Application for Current.

At least ten days before the supply of current is required in any premises, the consumer, or his contractor acting for him, must fill in and send to the Corporation's head office the form prepared for that purpose, copies of which can be obtained on application to the Corporation. This form, which must be signed by the consumer, states the number of lamps or other apparatus for which current is required, and the supply of current will be given on the understanding that the maximum current applied for is not exceeded.

Where a consumer desires to use current for Power, Heating or Cooking, it is recommended that a separate circuit should be run distinct from the lighting circuit. Attention is called to the following condition as to rate of charge:—
"If any lamps used for lighting purposes are connected

to or are supplied by means of a power circuit, lighting rates will be charged for the whole circuit."

At least four days' notice in writing must be given to the Corporation of any alterations being made to the wiring, or of additional lamps or other apparatus being added, and all such new work must be tested by the Corporation when finished, prior to the current being turned on to the new or altered circuits.

In the event of neglect of this rule, the Corporation is at liberty to cut off the whole of the installation until the tests have been made.

Consumers are specially cautioned against increasing the number or candle-power of their lamps without competent advice, as by so doing they may cause their wires to be dangerously overloaded.

Connection

to the Corporation's mains will be made free of charge where the premises are situated at a less distance than 60 feet along a public thoroughfare from mains already laid, but no work on private premises can be undertaken, beyond the fuse box mentioned below.

System of Supply.

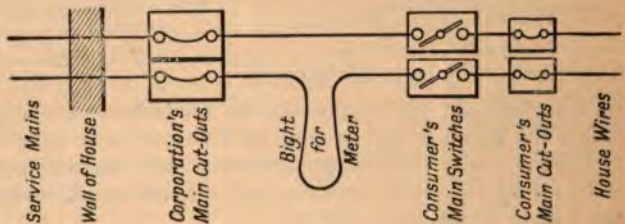
Continuous current will be supplied at a pressure of 200 volts. Consumers requiring a supply for lighting purposes in excess of 40 ampères will be connected on a double service, particulars of which can be obtained from the Corporation. Motors having an output of 4 h.p. and over will require special arrangements as specified on page 229.

Services.

The Corporation in all cases lay the service mains between their own mains and the consumer's premises. The Corporation will bring the service mains into or upon the consumer's premises at the nearest convenient point to their

service boxes, and will fix the ends of their mains into a fuse box. This fuse box will be supplied and fixed by the Corporation. The consumer's mains must be brought out as far as the fuse box and the ends left ready for sweating in, which will be done by the Corporation. The Corporation will supply, fix and keep in repair, a suitable meter on the consumer's premises on the house side of the main fuse. For connection to this meter the contractor must leave a bight of from 5 to 6 feet long, but the connection will in all cases be made by the Corporation. A rent will be charged quarterly for the hire of the meter.

The consumer must fix two single pole cut-outs and two single pole switches immediately following the meter thus :



The Corporation, on receiving proper notice in writing addressed to the Superintendent of Mains, will point out the position which their main fuse box and meter will occupy.

Main Fuses.

The Corporation's main fuses must under no circumstances whatever be inserted by the consumer or by contractors, but by the Corporation only. These will not be inserted until the wiring of the premises has been tested and passed. If at any time the main fuse should fail, the consumer should at once inform the Corporation, so that a new fuse can be inserted.

Wiring.

All the work upon consumer's premises must be carried out in accordance with the rules issued by the Institute of Electrical Engineers and the Fire Insurance Company under which the premises are insured.

Testing.

The contractor is to send notice to the Superintendent of Mains that the wiring is ready for testing at least four days before the supply is required. On receipt of this notice the Corporation will fix a date and time for testing. The contractor's representative must be present at this test, which will be made free of charge. If the work is not ready, or if it fail to pass the test, a fee of 10*s*. 6*d*. must be paid before another test can be made. The test is made from the Corporation's cut-out, and consists of an insulation test between the wires and between each wire and earth, when every branch fuse has been inserted, all switches turned on, and the lamps removed.

The test will be made in accordance with the rules of the Institution of Electrical Engineers, and the Corporation will not supply current to any installation which fails to reach the standard there specified.

In installations where there are any temporary wires or fittings, or where the work is incomplete, the Corporation must be duly informed, and they will not connect unless they are satisfied as to the precautions taken.

After the test the lamps must all be inserted, and they will be inspected to see that every lamp lights properly.

Subsequent additions to the lights must be tested in the same manner as the original lights. Neglect to give notice of such additions may involve, at the discretion of the Corporation, the whole supply being cut off until the proper tests have been made.

Inspection.

The Inspector or other authorized officer of the Corporation is to have free access at any reasonable times to ascertain the quantity of electricity supplied and to examine the meter and main fuse.

The official Board of Trade regulations provide that if the Corporation are reasonably satisfied, after making all proper examination by testing or otherwise, that there exists upon the premises of a consumer a leakage of such extent as to be a source of danger, then and in such case any officer, duly authorized by the Corporation, may for the purpose of discovering whether the leakage exists upon the consumer's premises, by notice require the consumer to permit him to inspect and test the wires and fittings belonging to the consumer.

If, on such testing, the officer discovers a leakage from the consumer's wires exceeding 1/10,000 part of the maximum supply current to the premises, or if the consumer does not give all due facilities for inspection and testing, the Corporation shall forthwith discontinue the supply of energy to the premises in question, giving immediate notice of the discontinuance to the consumer, and shall not re-commence the supply until they are reasonably satisfied that the leakage has been removed.

Motors.

The starting and stopping switch and resistance must be so arranged that the first contact gives not more than 10 per cent. of the full working current, and that the increase or decrease of current takes place by steps of not more than 10 per cent. The starting or stopping of the motor must not, under any circumstances, cause visible disturbance to any lights upon its own or neighbouring circuits.

Motors having an output of 4 h.p. and over will be connected to the Corporation's 400 volts mains, and must comply with the Board of Trade regulations, which at present are as follows :—

INTERNAL WIRING OF BUILDINGS

1. A joint application to be sent to the Board of Trade signed by the consumer and the Corporation. (Forms of application can be obtained from the Corporation.)
2. The frame and shaft of every electric motor intended to be worked at the pressure specified (400 volts) shall be efficiently connected with earth.
3. The electric lines forming the connections to motors, or otherwise in connection with this supply, and placed upon the premises of the consumer, shall be, as far as practicable, completely enclosed in strong metal casing efficiently connected with earth.
4. The supply to every motor shall be controlled by means of a sufficient cut-off switch, placed in such a position as to be easily handled by the person in charge of the motor, and connected so that by its means all pressure can be cut off from the motor itself, and from any regulating switch, resistance or other device in connection therewith.

   Efficient fuses or other automatic cut-outs shall also be provided, so as to protect the branch circuit on each side of every motor from excess of current.

   The above-mentioned switches and cut-outs shall be so enclosed and protected that there shall be no danger of any shock being obtained in the ordinary handling thereof, or from any fire being caused by their normal or abnormal action.
5. A notice shall be fixed, in a conspicuous position, at every motor and switch-board in connection with this supply, forbidding unauthorized persons to touch the motor or apparatus.

RULES OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

GENERAL RULES RECOMMENDED FOR WIRING FOR THE SUPPLY OF ELECTRICAL ENERGY.

1. These Rules embody the requirements and precautions which the Institution of Electrical Engineers has framed to secure satisfactory results with a supply of electrical energy at low pressures, not exceeding 250 volts. They are intended to include only such requirements and precautions as are generally necessary, but they are intended neither to take the place of a detailed specification, nor to instruct untrained persons.

For medium pressures exceeding 250 volts but not exceeding 650 volts, the additional requirements and precautions are contained in the Board of Trade Regulations which are set out on pages 256, 257, as far as they relate to conditions similar to those intended to be covered by these Rules. The Home Office Special Rules for the Installation and Use of Electricity in Mines are set out on pages 259 to 272.

Fire Offices.

2. Notice of the introduction of wiring should in all cases be given to the Fire Offices insuring the risk, and their suggestions respecting any details not covered by these rules or any deviations arising from special conditions should be adopted. When the supply is to be obtained from an external source, notice should be given to the suppliers before wiring.

INTERNAL WIRING OF BUILDINGS

Definitions of Certain Terms used in these Rules.

3. *Three-wire System.*—A three-wire system is one in which three conductors are maintained at different potentials, the conductor at a potential intermediate between the highest and lowest being common to all lamps or other consuming devices supplied on either side of the system.

4. *Neutral Conductor.*—The neutral conductor of a three-wire system is the conductor which is at a potential intermediate between the potentials of the outer conductors.

5. *Outer Conductor.*—The outer conductors of a three-wire system are those between which there is the greatest difference of potential.

> *Note.*—This specialized use of the word "outer" must not be confused with the non-technical use of the word when applied to the external conductor of a concentric main which physically surrounds the other conductor or conductors of such main.

6. *Earthed Conductor.*—A conductor is said to be earthed when it is connected to the general mass of the earth in such a manner as will ensure at all times an immediate and safe discharge of electrical energy.

7. *Uninsulated Conductor.*—A conductor is said to be uninsulated when, although not earthed, no provision is made by the interposition of a dielectric or otherwise for its insulation from earth.

8. *Bunching of Conductors.*—Conductors are said to be bunched when more than one is contained within a single duct or groove.

9. *Single-pole Switches.*—Single-pole switches are switches interrupting one conductor only of a circuit.

10. *Linked Switches.*—Linked switches are single-pole switches fixed on conductors of different polarity

linked together mechanically so as to operate simultaneously.

11. *Dielectric.*—A dielectric is any material which by its nature or the method of its application to a conductor permanently offers high resistance to the passage of current and of disruptive discharge through itself.

12. *Grade of Insulation.*—A cable is said to be of I.E.E. 600 or 2,500 megohm grade when its minimum insulation is that shown in cols. 5 and 6, respectively, of the Table when tested at 60 deg. F. (15·6 deg. C.) after one minute's electrification and twenty-four hours' immersion in water.

13. *Ventilated Motors.*—A ventilated motor is one in which, while ventilation is provided for, access to the armature, field coils, and other live parts is only to be obtained by opening a door in, or removing a part of, the enclosing case.

14. *Totally Enclosed Motors.*—A totally enclosed motor is one in which all the live parts, whether insulated or not, are totally enclosed, as in paragraph 13, but without provision for internal ventilation.

LOW PRESSURES NOT EXCEEDING 250 VOLTS.

General Arrangement.

Control.

15. Every system must be protected by linked main switches or linked switch-fuses under the control of the consumer, and these must be easily accessible and placed as near the generator or the entry of supply as circumstances permit.

Interruption of Current.

16. When one of the main conductors of a system of supply is earthed, no interruption of the current is permitted in a conductor connected to the earthed main, unless a simultaneous break is effected on the non-earthed conductor. Hence, to ensure the current being interrupted simultaneously on both the earthed

and the non-earthed wires, no switch or switch-fuse that is not linked to another switch or switch-fuse on the non-earthed conductor may be inserted in any conductor connected to an earthed main.

Fuses in Multiple-wire Systems.

17. No fuse may be placed in the neutral conductor of a three-wire or other multiple-wire system, but fuses must be placed on both conductors of two-wire circuits branching therefrom. This does not prevent the use of a disconnecting link in the neutral conductor for testing purposes.

Uninsulated Returns.

18. When the wiring is such that one conductor is uninsulated at all points—such as a bare return to a concentric system—no switch or fuse may be placed in that conductor, and the said conductor must be efficiently earthed.

Introduction of Multiple-wire System into Premises.

19. When the pressure between the outer conductors of a three-wire system exceeds 250 volts and the three wires of the system or two pairs of wires are brought into premises, the supply shall be given to two pairs of terminals arranged so as to minimize the danger of shock, and the wiring from these terminals shall be kept distinct throughout, and so arranged that a person cannot simultaneously touch two points respectively in contact with the outer conductors. In the case of other multiple-wire systems similar principles shall be applied.

Protection in Polyphase Systems.

20. When energy is taken from all the conductors of a two-phase or three-phase system, the conductors must be protected, either by an automatic triple-pole circuit-breaker, or by a fuse on each pole in conjunction with a triple-linked switch; or by three switch-fuses.

Current in Circuits and Sub-circuits.

21. Conductors must radiate from distributing centres, and in large systems from those centres to sub-centres, so that no final sub-circuit carries more than 5 ampères up to 125 volts, or more than 3 ampères from 125 to 250 volts, for incandescent lighting. The sub-circuits for small heaters must not

carry more than 15 ampères up to 125 volts, or more than 10 ampères from 125 to 250 volts, and they must be protected by a fuse on each pole. Heaters and apparatus exceeding the 10-ampère limit must comply with paragraph 91 (*e*) (1) and (2).

Fuses in Sub-circuits. 22. Every sub-circuit must be protected on each pole by a fuse (par. 18).

Bunching. 23. When protected from mechanical injury by metal tubes or conduits [par. 46 (*a*)], conductors of opposite polarity may be bunched, and when carrying small currents for incandescent lighting, from sub-centres, as in paragraph 21, they may also, if without joints, be bunched when the protecting tubing or casing is non-metallic. If the supply is alternating and the protection metallic, the lead and return conductors must be bunched.

Earthing. 24. Where metallic sheathing or tubing is used it must be electrically and mechanically continuous and connected to earth. The conductor (earth-wire) used for the purpose of earthing must be of copper, and of a sectional area not less than that of No. 14 S.W.G.

Gas-pipes. 25. There must be no contact between conductors (or their insulating material, metallic sheathing or tubing) and gas-pipes. Non-conducting distance-pieces must be used where necessary.

Gas-pipes. 26. Gas-pipes must never be used to obtain an earth connection.

Concentric Wiring. 27. Where concentric wiring with an uninsulated external conductor is used, this system of wiring must be employed throughout, except for fittings and pendant flexibles.

Earthing in Concentric Wiring. 28. When the mains are earthed at one point, the external conductor of a concentric system is the conductor to be connected to the earthed main.

Inflammable Gases and Dust. 29. In places where inflammable or explosive dust, gases, or vapours are liable to be present, dynamos, arc lamps, Nernst lamps, and connectors must not be

used. In such situations, incandescent lamps must, with their holders, be enclosed in air-tight fittings of thick glass; switches, fuses and resistances must be enclosed in gas-tight boxes or break under oil; and motors, with their live parts, starters, terminals and connections, must be completely enclosed (par. 91 (*d*)] in flame-tight enclosures made of uninflammable material.

30. Except where completely enclosed in a metallic casing, no switch, ceiling-rose, cut-out, connector, or other electrical accessory, may be mounted directly upon any surface of a condensing or humid nature, such as masonry or brickwork, but must, in addition to its own mount, be fixed upon a base block rendered impervious to moisture. **Damp Surfaces.**

Conductors—Size and Conductivity.

31. Excepting for wiring fittings, the sectional area (see Table) of any copper conductor must not be less than that of No. 18 S.W.G. It must be assumed that, at least, 60 watts may be consumed at any point (par. 97). **Size.**

32. The size of conductors within a building will, subject to paragraphs 31 and 35, be determined by the permissible drop in volts, which should not exceed 2 per cent. on lighting circuits. **Size.**

33. Covered copper conductors should be of soft copper, and should have a conductivity not less than that of the E.S.C. standard (par. 113); where sulphur compounds are present in any part of the insulating material the copper in contact with the insulating material must be protected thereform by tinning or otherwise. **Conductivity.** **Sulphur.**

34. All covered copper conductors having a greater area than that of a No. 14 S.W.G. wire must be stranded. **Stranding.**

Table. 35. The Table appended shows the sizes of copper conductors which will safely carry currents up to 750 ampères, and the length in yards of single conductor in circuit for each volt of fall of potential when the maximum continuous current is in use.

CONDUCTORS—INSULATION.

Temperature. 36. Conductors, except as provided in paragraph 52, must be specially insulated with material which does not deteriorate at the highest temperature to which it will be subjected: for instance, rubber must not be allowed to exceed 130 deg. F. (54·4 deg. C.), and paper or fibre must not be allowed to exceed 176 deg. F. (80 deg. C.)

37. The insulating material on any conductor other than a flexible must be throughout either—

Vulcanized Rubber. A. A dielectric, such as vulcanized rubber of the best quality, which is impervious to moisture and only needs mechanical protection (par. 46). ("Dielectric" does not include braiding or taping.) Or

Paper and Fibre. B. A dielectric, such as paper or fibre, which must be kept perfectly dry, and therefore needs to be encased in a waterproof sheath, generally of soft metal, such as lead, drawn closely over the dielectric.

Thickness. 38. The radial thickness of vulcanized rubber must be not less than that given in columns 9 and 10 of the Table, or in proportion thereto. The radial thickness of dielectrics of Class B must be not less than that given in Column 11 of the Table. The dielectric must not soften sufficiently to allow decentralization at a lower temperature than 176 deg. Fahr. (80 deg. C.)

Tests. 39. The dielectric must be such that when the insulated conductor has been immersed in water for twenty-four hours it will, while still immersed, withstand 2,000 volts for half an hour between the con-

ductors or between the conductor and the water, the test pressure being applied with alternating current at a frequency of 50, the E.M.F. curve being as nearly as possible a sine-wave.

40. The minimum insulation resistance should be that given in columns 5 and 6 of the Table for vulcanized rubber, and that in column 7 for Class B, the test being made at 60 deg. F. (15·6 deg. C.) after one minute's electrification at 500 volts, and after the insulated conductor has been immersed in water for the twenty-four hours immediately preceding the test. **Insulation Resistance.**

41. The insulation resistance between the members of twin-conductors should be not lower than the corresponding insulation resistances in the Table. **Twin Conductors.**

42. Conductors insulated as in Class A must be taped and braided if drawn into conduits, and at least taped if laid in casing. **Taping and Braiding.**

43. Concentric conductors (pars. 18, 27, and 28) should in all respects conform to the requirements laid down for single conductors; the insulation resistance of the dielectric separating the two conductors must be that given in the Table for single conductors having the same diameter as the inner conductor. The insulation resistance of the dielectric on the external conductor, where insulated, must be that given in the Table for single conductors having the same diameter as the outside diameter of the external conductor. **Concentric Conductors.**

CONDUCTORS—FLEXIBLE.

44. Flexibles must be of a sectional area not less than that equivalent to No. 22 S.W.G.,[1] and they must be made up of wires twisted together on a short lay, the sectional area of each wire being not greater than that of No. 36 S.W.G. The insulating material **Size.**

[1] The following have a sectional area equivalent to No. 22 S.W.G.: 34/40, 22/38, 14/36.

Dielectric. used as the dielectric must be pure rubber equal to washed Para rubber of the best quality or vulcanized rubber of the best quality. Pure rubber insulation is best suited for flexibles intended for use with pendants. Pure rubber must be laid on in two layers, care being taken that each layer overlaps, and the radial thickness of the dielectric must not be less than 20 mils.

Tests and Thickness of Dielectric. Each coil of pure rubber flexible must be tested for 15 minutes with a pressure of 1,500 volts alternating between the conductors at a frequency of 50. Vulcanized rubber flexible must be insulated with one layer of pure rubber and two layers of vulcanized rubber, and the radial thickness of the dielectric must not be less than 34 mils. Each coil of vulcanized rubber flexible must be tested for 15 minutes with a pressure of 1,500 volts alternating at a frequency of 50, after twenty-four hours' immersion in water and while still immersed.

Sulphur. When sulphur is present, the insulating material must not be in direct contact with the copper wires.

Where Permitted. 45. Flexibles (pars. 25, 51, 75 and 76) may be used only for attaching to pendant or portable appliances, or for sub-circuits under the conditions of paragraph 46 (c). They must not be used in any position out of sight except where passing directly through walls, when they must be protected in incombustible water-tight conduits. They must not pass through floors.

Connections. The connection between flexibles and hard wires may only be effected by means of screw-down terminals in junction boxes or ceiling roses, and where flexibles from fittings must pass into a ceiling they must be enclosed in conduits up to a metal junction box.

Conductors—Fixing and Supporting.

46. Conductors (excepting flexibles) insulated as in Classes A and B (par. 37):—

Steel Conduits. (*a*) May be enclosed in steel conduits with details and accessories complying with the British

Standard Specification for " Steel Conduits for Electrical Wiring " or in brass or copper conduits ; but all conduit systems must be electrically and mechanically continuous throughout, have all outlets bushed to prevent abrasion, and be connected to earth (pars. 25 and 26). In dry places isolated single lengths of tubing need not be earthed if adequately enamelled, or otherwise insulated, externally. In damp places the conduit system must be water-tight. Conduits must be efficiently drained if liable to internal condensation. Sharp bends or elbows are prohibited, but inspection elbows are permissible.

(*b*) May be enclosed in wood casing in dry places where not buried in plaster or cement nor exposed to moisture. Unless efficiently protected from drip, wood casing must not be fixed immediately below, and in no case must touch, water pipes. Conductors carrying more than 5 ampères must be laid singly in separate grooves. **Wood Casing.**

(*c*) May be without mechanical protection (i.e., without conduit, armouring, etc.) where not exposed to injury, but they must be supported in such a manner as to secure the permanent spacing of the conductors from walls, ceilings, and all structural metal work and metal piping. When carrying more than 5 ampères they must also be spaced from each other, unless they are of the multiple-core or concentric types. Such spacing is not, however, necessary if the conductors are lead-covered (par 25). **Conductors without Mechanical Protection.**

47. Unenclosed lead-covered conductors must be supported on a continuous wood fillet or fastened by broad clips, which, in damp places, must be of lead. **Lead-covered Conductors.**

Floors and Walls.

48. Conductors where exposed to injury (e.g., where passing out of floors), must be specially protected by stout conduits or boxing, and where passing through walls, partitions, or ceilings, they must be enclosed in porcelain or other protecting conduits.

Party Walls and Floors.

49. Conductors passing through party walls or fire-resisting floors must be provided with special protection, such as a close-fitting porcelain or other incombustible tube, to prevent the spread of fire through the openings. When the end of the tube

Rain.

is outside the building, it should be bell-mouthed or bushed, and turned downwards.

Plaster.

50. Conductors buried in plaster must be provided with mechanical protection.

Staples.

51. Metal staples must not be used for fixing unarmoured conductors.

CONDUCTORS—BARE.

Travelling Cranes.

52. Bare conductors without any insulating covering may be used indoors—

(*a*) As collector wires for travelling cranes and similar appliances, but they must be so supported upon insulators as to prevent contact between the conductors themselves, or between the conductors and the walls or the structural or other metal work, should a collector wire be displaced from any insulator. The insulation at each straining point (i.e., at the end of each wire) must consist of two strain insulators placed in series. The current must be under complete control by means of a switch and a fuse, or a switch-fuse, in each supply conductor. Lightning arresters must be fitted if the bare wiring extends to an exposed position in the open.

(*b*) As trolley wires for locomotives, jib cranes, and similar appliances, but they must be insulated by means of two strain insulators places in series between each wire and "earth" at their points of support. Wall rosettes or brackets used as supports for span wires should not be fixed within one foot of any gas pipe. Controlling switches and fuses, or switch-fuses, and lightning arresters must be provided as under (*a*). Loco-motives, Jib Cranes.

(*c*) As battery connections, but such conductors must be well spaced from each other and from all structural or other metal work, and be rigidly supported on insulators. Batteries.

(*d*) For other purposes, under special circumstances and in positions inaccessible to unauthorized persons, but permission for such use should be previously obtained from the Fire Offices insuring the risk. Power Purposes.

Joints and Connections.

53. Joints constitute a source of weakness and should be avoided whenever possible.

54. Joints, when unavoidable, must be accessible, and they must be mechanically and electrically perfect to prevent heat being generated. All joints must be soldered. Soldering fluids containing acid, or other corrosive substances, must not be used.

When junction-boxes are used they must be so constructed that— Junction Boxes.

(*a*) the conductors cannot be readily short-circuited;

(*b*) the insulation between opposite poles is rigid and durable;

(*c*) the connections do not heat;

(*d*) if used in damp places, moisture is excluded by suitable means.

Jointing Conductors.

55. In jointing conductors the braid, tape or lead must be carefully removed without damage to the dielectric, and for a sufficient length to ensure a thorough union between the dielectric and the material used to insulate the joint. If the insulating material is not waterproof, it must be covered with an impervious sleeve or box, which must make a water-tight joint on each side of the junction. Care must be taken to exclude moisture during the operation.

Looping.

56. Looping should be employed to avoid joints on small conductors.

Connections at Terminals.

57. Where conductors are connected to switches, fuses, junction-boxes, or other appliances, the whole of the separate wires forming the stranded or flexible conductor must be contained within the terminal. The dielectric must not be bared back further than to allow the conductor to enter the terminals properly, and the ends of the insulation Class B should be sealed.

Moisture at Terminals.

58. With dielectrics of Class B, the exposed ends of conductors, where they enter the terminals of switches, fuses, and other appliances, must be protected from moisture which might creep along the insulating material within the waterproof sheath.

Waterproofing at Terminals.

59. Where conductors enter the terminals of switches, fuses and other appliances, the braid, lead, or other covering must be cut back from the end of the dielectric, which must be waterproofed. In damp places the strands of conductors of Class B should be soldered to prevent moisture creeping along the copper beneath the insulating material.

Soldering to Lugs.

60. Conductors of larger sectional area than that of 7/18 S.W.G. must be soldered to proper lugs for connection. Where there is any possibility of stress on the lugs the conductors must be secured, in addition to the soldering, by some mechanical device, such as one or more grub-screws.

Switch and Distribution Boards.

61. Main and distribution switch and fuse boards must be fixed in a dry situation, and be so arranged that a fire thereon cannot spread, whether occurring at the front or back. Their bases must be of incombustible and insulating material, with moisture-proof bushes fitted at the points of support if the material is hygroscopic. The possibility of a permanent arc must be prevented either by sufficient spacing of all live parts, or by the use of separating partitions. Position and Construction.

62. Connections at the back of main boards must be accessible, symmetrically placed, and spaced apart, and, unless protected from acid fumes, must not project into battery rooms. Accessibility.

63. Switchboard circuits should be labelled for identification. Labels.

64. No open-type fuses may be placed at the back of switchboards. Fuses.

65. The cases of instruments, if metallic, must be insulated from the circuits. Metal Cases.

66. Every voltmeter or pilot lamp with its connecting wires should be protected by a fuse on each pole. Fuses.

67. Combination switch and fuse boxes must be so arranged that it is possible to operate a switch without uncovering the fuses, if of the open type. Combination Boxes.

68. When fuses are of the open type and grouped together, the case of the distribution board will be a sufficient protection from the fused metal provided the distance from cover to fuse exceeds one inch with glass-fronted cases. If made of wood, the case must be protected with fire-resisting material, and a clearance of one and a half inches should be provided. Fused Metal.

Switches.

69. Switches (pars. 29 and 30), whether fixed separately or combined with lampholders or fittings, must comply with the following requirements :—

Overheating. (*a*) Overheating must not take place at the point of contact or elsewhere, when the full current flows continuously.

Size. (*b*) They must be incapable of forming a permanent arc when breaking circuit. Switches should be tested with pressures and currents 50 per cent. in excess of those which will be used on the circuits for which they are intended.

Bases. (*c*) The bases must be of incombustible non-conducting and moisture-proof material.

Covers. (*d*) Unless placed in an engine-room or in a compartment specially arranged for the purpose, switches must have their live parts covered. The covers must be of incombustible material, and must be either non-conducting or of rigid metal, and clear of all internal mechanism. For more than 5 ampères, at pressures over 125 volts, metal covers must be lined with insulating material.

Boxes. (*e*) Switches in positions liable to injury, or contact with goods, should be further protected by an open-fronted box or other suitable guard.

Handles. (*f*) Handles must be insulated and so arranged that the hand cannot touch live metal, or be injured through an adjacent fuse blowing.

Fuses.

Over-heating. 70. Fuses (pars. 29, 30, and 68) must comply with the following requirements :—

Size. (*a*) No overheating of any part must take place when the full current flows continuously.

(*b*) They shall effectually interrupt the current when a short-circuit occurs, and also when the current through them exceeds the working rate by 200 per cent., the current flowing

under the normal pressure, but they must be so proportioned to the current to be carried that no conductor protected by them can be raised in temperature above that specified in paragraph 36.

(*c*) The terminals must be so spaced apart or screened that an arc cannot be maintained when the fuse is blown. **Terminals.**

(*d*) The bases must be of incombustible, non-conducting, and moisture-proof material. **Bases.**

(*e*) Unless placed in an engine-room or in a compartment specially arranged for the purpose, fuses must have covers to retain the fused metal. The covers must be of incombustible material, and must either be non-conducting or of rigid metal lined with insulating incombustible material, and clear of all live parts. Small, close-fitting covers should be perforated for ventilation. **Covers.**

(*f*) Fuses must not be placed in wall-sockets, ceiling roses, lampholders, or connectors. **Wall Sockets, etc.**

(*g*) Separate single fuses, and not double-pole fuses, must be used on circuits where the pressure exceeds 125 volts. **Pressures over 125 volts.**

71. Branch fuses must be grouped together in accessible positions in sight, and should be symmetrically placed and labelled for each circuit. **Branch Fuses.**

72. *Note.*—Hard metal is recommended for fuses. Soft metal fuses should be soldered to hard metal contact pieces. As a practical guide, fuses may be considered too large if they are not perceptibly warm to the touch when carrying full load, and too small if they hiss when moistened. Precautions against shock must be taken when applying this test.

CONNECTORS.

Construction and Fixing.

73. Connectors (pars. 29 and 30) must be capable of withstanding a test with pressure and current 50 per cent. in excess of those for which they are intended. Fixed connectors must have incombustible bases, and in damp places special water-tight connectors must be used. Where the fixed part of a connector is attached to a floor it must be so arranged that no dust or water can accumulate, that all contacts are well below the floor-level, and that any possibility of danger from contact of live metal with carpets is avoided. Provision should be made to facilitate inspection.

74. Connectors must be constructed so that they cannot be readily short-circuited. Clearances should be such that an arc cannot be started if the connector is pulled out while the current is flowing.

75. Flexibles for portable fittings must end in a connector.

Switches.

76. Every connector, or group of connectors, must be independently controlled by a switch on the live side of the connector. To avoid leaving the flexibles live, it is perferable that the portable fittings themselves should not be provided with switches.

CEILING ROSES.

77. Ceiling roses (par. 30) must comply with the following requirements :—

Bases.

(*a*) The bases must be of incombustible, non-conducting and moisture-proof material ;

Covers.

(*b*) The covers must be of incombustible material, and must be either non-conducting, or of rigid metal clear of all live parts ;

Terminals.

(*c*) The terminals must be relieved of the direct pull of the attached conductor and fitting, and be so arranged that no short circuit can take place ;

(*d*) They must not be used for attachment to more than two pairs of flexibles, unless specially designed for multiple pendants. **Flexibles.**

Fittings for Supporting Lamps.

78. Wherever brackets, electroliers, or standards require to have the conductors threaded through tubes or channels formed in the metal work, these must be of ample size and have no sharp angles or projecting edges, which would be liable to damage the insulating material, and the open ends should, where possible, be bushed. **Tubes and Channels.**

79. Where possible the conductors should be carried without joints through the fittings to the lamps; but where connections at the fittings are unavoidable, special care must be taken to make the joints equal in conductivity and insulation to the rest of the work (par. 45). **Joints.**

80. Combined gas and electric fittings must not be used. **Gas-fittings.**

81. If disused gas-fittings are adapted for electric light, they must be entirely disconnected from the gas-pipes. **Gas-pipes.**

Lampholders.

82. Lampholders (pars. 29 and 86) must—

(*a*) be incombustible;

(*b*) be specially designed if for currents above 1½ ampères;

(*c*) not be hung from flexibles exposed to the weather;

(*d*) not contain a switch if for pressures above 250 volts.

83. Switch lampholders must be controlled, preferably in groups of not more than ten, by a wall-switch. **Wall Switches**

ARC LAMPS.

Globes and Guards.

84. Arc lamps (par. 29) must—
   (*a*) be guarded by lanterns or globes arranged to intercept falling particles of carbon;

   Note.—Lanterns or globes may be dispensed with where an open arc is essential, as in photography, and where no combustible material is present, as in a foundry; but the flooring immediately under the lamp, if of a combustible nature, must be protected from falling particles of carbon. Open inverted arc lamps, in the presence of combustible matter, must have metal reflectors rigidly attached beneath the arc, which at all times must be below the level of the upper edge of the reflector. The reflector must project at least 15 inches measured horizontally beyond the arc on all sides.

   (*b*) be insulated from their support;
   (*c*) be fixed so that their cases cannot come into contact with any metallic object;
   (*d*) have their leading-in wires protected from rain;
   (*e*) be controlled by linked switches and protected by a fuse on each pole.

INCANDESCENT LAMPS.

Combustible Materials.

85. Incandescent lamps must—
   (*a*) Not be placed in close proximity to combustible materials unless specially protected; shades made of combustible materials must be kept free from contact with the lamps and their holders by suitable guards or supports; celluloid or similar material must not be used for shades and candle tubes;

(*b*) Be fitted with guards if placed in positions where goods are liable to be stacked in contact with them; **Guards.**

(*c*) With their holders, be enclosed in air-tight fittings of thick glass, if placed in positions where they are exposed to inflammable vapour or gas or to excessive dust or flyings, as in dust-rooms and in raising-rooms. **Inflammable Gases and Dust.**

86. Lamps caps of which the insulating material is hygroscopic must not be used in damp places unless the lampholder is insulated from its support. **Caps.**

87. Lamps of the Nernst type must comply with the requirements of paragraphs 29, 84 (*a*), (*b*), (*c*), (*d*), and 85. **Nernst Lamps.**

HEATERS.

88. Heaters [pars. 21 and 82 (*b*)] must be—

(*a*) so constructed and mounted that their supports and connections cannot become overheated, precautions being taken with regard to their surroundings as in the case of non-electrical heating appliances. They must not be placed in close proximity to combustible materials, unless suitably protected; **Over-heating.**

(*b*) independently controlled by a switch on the live side of the connector, the connectors being so arranged that the live end of the coupling is not exposed to accidental short-circuiting or injury. **Switches.**

89. Radiator circuits must be protected by a fuse on each pole and by a wall-switch in each room. **Fuses and Wall-switches.**

RESISTANCES, CHOKING COILS, AND ALTERNATING CURRENT TRANSFORMERS.

90. The live parts (par. 29) of the above must be— **Supporting.**

(*a*) carried on frames or supports and enclosed in cases. These frames, supports, and cases

must be of incombustible material efficiently insulated from the conductors ;

Ventilation of Cases. (*b*) amply ventilated. Where there is danger of inflammable dust or flyings entering, apertures in the cases must be protected by fine-mesh wire gauze or by finely-perforated sheet metal ;

Size. (*c*) so proportioned that their cases cannot attain a temperature exceeding 176 deg. F. (80° C.) ;

Combustible Materials. (*d*) so fixed that no unprotected combustible material is within 6 inches of the frames or cases containing them, or within 24 inches measured vertically above them.

Motors.

91. Motors (par. 29) rated at more than one-third of a horse-power must comply with the following requirements :—

(*a*) They must be protected from damp, dust, and mechanical injury.

Combustible Materials. (*b*) They must be so placed that no unprotected woodwork or combustible material be within a distance of 12 inches from them measured horizontally, or within 4 feet measured vertically above them, unless they are of a totally enclosed type (par. 14).

Wood Floors. (*c*) When mounted upon wood flooring, unless of the totally enclosed or ventilated type (par. 13), they must have a sheet of metal inserted between them and such flooring. If elevated over wood flooring they must either rest upon a metal plate or have a metal plate suspended immediately below them.

Inflammable Dust. (*d*) In positions exposed to inflammable dust or flyings, or where combustible materials are

manipulated or stored, they must be either of the totally enclosed or of the ventilated type, provided that any ventilating openings in the cases of continuous-current machines are protected by fine-mesh wire gauze or by finely perforated sheet metal, and that all slip rings, commutators, and brushes are totally enclosed. Inspection openings fitted with plate glass or fine-mesh wire gauze are allowed. Induction motors may have unprotected ventilating holes in their metal cases, but slip rings or brushes or any sliding contacts must be completely enclosed in metal cases.

(*e*) They must be controlled by a switch and a fuse, or by a handgrip fuse, or by a circuit-breaker, on one conductor; and by one of these devices on the other conductor (par. 18). **Control.**

(*f*) The starting gear of a continuous-current motor must consist of a regulating switch and a series resistance, fitted with a no-volt release. **Starting Gear.**

(*g*) The shunt circuit of any motor must be so connected that the field is excited before the armature circuit is completed. **Shunt Circuit.**

(*h*) Every alternating-current motor must be provided with a suitable starting device and with a no-volt release. Large motors should have linked circuit-breakers on the conductors. **Alternating-current Motors.**

DYNAMOS.

92. Dynamos (par. 29) must comply with the following requirements:—

(*a*) They must not be placed in positions exposed to inflammable dust or flyings, nor where combustible materials are manipulated or stored. **Inflammable Dust.**

(*b*) They must be protected from damp, dust, and mechanical injury.

Combustible Materials. (*c*) They be so placed that no unprotected woodwork, or other combustible material, be within a distance of 12 inches from them measured horizontally, or within 4 feet measured vertically above them.

Wood Floors. (*d*) When mounted upon or above wood flooring, they must have a sheet of metal inserted between them and such flooring.

Control. (*e*) They must be controlled by a switch and a fuse, or by a circuit-breaker, on one conductor; and by one of these devices on the other conductor (par. 18).

Accumulators and other Batteries.

Ventilation. 93. The room in which accumulators or primary batteries are placed must be well ventilated (par. 29).

Insulation. 94. The case of each cell must stand on insulators. Glass cells should have an intermediate support to distribute the strain.

Connectors. 95. Bare conductors [par. 52 (*c*)] should be used for end and regulating cell connections; and all regulating cells must be protected by a fusible connector at each cell.

Control. 96. The method of control must be as described in paragraph 91 (*e*).

Testing.

Insulation Resistance to Earth. 97. The insulation resistance to earth of the whole or any part of the wiring must, when tested previously to the erection of fittings and electroliers, be measured with a pressure not less than twice the intended working pressure, and must not be less in megohms than 30 divided by the number of points (par. 31) under test. For this purpose the points are to be counted as the number of pairs of terminal wires from which it is

proposed to take the current, either directly, or by flexibles, to lamps or other appliances.

98. Current must not be switched on until the following test has been applied to finished work :—

The whole of the lamps having been connected to the conductors and all switches and fuses being on, a pressure equal to twice the working pressure must be applied, and the insulation resistance of the whole or any part of the installation must not be less in megohms than 25 divided by the number of lamps. When all lamps and appliances have been removed from the circuit, the insulation resistance between conductors must not be less than 25 megohms divided by the number of lamps. The insulation of any individual sub-circuit (par. 21) must not fall befow 1 megohm. Any motor, heater, arc lamp, or other appliance may be connected to the supply of electrical energy provided that the insulation of the parts carrying the current measured as above, is greater than 1 megohm from the frame or case. **Testing of Circuits.**

99. The value of systematically inspecting and testing apparatus and circuits cannot be too strongly urged. Records should be kept of all tests, so that any gradual deterioration of the system may be detected. Cleanliness of all parts of the apparatus and fittings is essential. **Inspection.**

100. Before making any repairs or alterations, the circuits which are being attended to must be entirely disconnected from the supply. **Repairs.**

TABLE.

101. *Columns* 1 *and* 15 give the size of the conductors in common use. Cables are shown thus :—19/16, viz., 19 wires of number 16 standard wire gauge, or 19·082″ meaning 19 wires each of which is ·082 inch in diameter.

102. *Column* 2 gives the maximum current permissible in conductors laid in casing or tubing, provided the external temperature does not exceed

100 deg. F. (37·8 deg. C.). The maximum current for any conductor may be calculated from the formula—

$$\text{Log } C = 0{\cdot}82 \log A + 0{\cdot}415,$$
$$\text{or } C = 2{\cdot}6\, A^{0.82}$$

(Where C=current in ampères,
and A=sectional area in 1000ths of a square inch.)

103. *Column* 3 gives the approximate current density in ampères per square inch corresponding to Column 2.

104. *Column* 4 gives the total length in yards of the conductor in circuit (lead and return) for one volt drop when the current in each conductor is that given in Column 2.

105. *Columns* 5 *and* 6 give the minimum insulation resistance (par. 40) with vulcanized rubber in megohms per mile. These insulation resistances are those of cables of I.E.E. 600 and 2,500 megohm grades respectively.

106. *Column* 7 gives the minimum insulation resistance (par. 40) which is advisable in practice for fibre-covered cables lead-covered.

107. *Column* 8 gives the resistance of the conductor per 1,000 yards in Board of Trade standard ohms.

108. *Columns* 9 *and* 10 give the minimum thickness of dielectric of Class A as defined in paragraph 38.

109. *Column* 11 gives the minimum thickness of dielectric of Class B as defined in paragraph 38. Special cables, such as twin or 3-core cables, are not included in this column.

110. *Column* 12 gives the minimum thickness of lead for cables of Class B. This column does not apply to vulcanized rubber cables which may be lead-covered.

111. *Column* 13 gives the weight of copper conductors of the gauge given in lbs, per 1,000 yards.

112. *Column* 14 gives the nominal section of the conductor in square inches.

113. The data for the resistances and weights of copper conductors are based on the E.S.C. standard as defined by the Engineering Standards Committee as follows :— **Standards.**

A wire one metre long weighing one gramme and having a resistance of 0·1539 standard ohms at 60 deg. F. (15·6 deg. C.) is taken as the Engineering Standards Committee (E.S.C.) standard for hard-drawn high conductivity commercial copper.

Hard-drawn copper is defined as that which will not elongate more than 1 per cent. without fracture.

A wire one meter long, weighing one gramme and having a resistance of 0·1508 standards ohms at 60 deg. F. (15·6 deg. C.) is taken as the Engineering Standards Committee (E.S.C.) standard for annealed high conductivity commercial copper.

Copper is taken as weighing 555 lb. per cubic foot (8·89 grammes per cubic centimetre) at 60 deg. F (15·6 deg. C.) which gives a specific gravity of 8·90.

An average temperature coefficient of 0 00238 per degree F. (0·00428 per degree C.) is adopted.

A variation of 2 per cent. from the adopted standard of resistance is allowed in all conductors.

A variation of 2 per cent. from the adopted standard of weight is allowed in all conductors.

An allowance of 1 per cent. increased resistance, as calculated from the diameter, is allowed on all tinned copper conductors between diameters 0·104 and 0·028 (Nos. 12 and 22 S.W.G.) inclusive.

For the purpose of calculation of tables, a lay, involving an increase of 2 per cent. in each

wire except the centre wire, for the total length of the cable is taken as the standard.

The legal standard wire gauge, as fixed by Order in Council dated August 23, 1883, is adopted as the standard for all wires.

BOARD OF TRADE REGULATIONS (1905) FOR MEDIUM PRESSURES, EXCEEDING 250 VOLTS, BUT NOT EXCEEDING 650 VOLTS.

[*The regulations reprinted here are only those relating to the conditions intended to be covered by the Wiring Rules.*]

MOTORS.

Earthing.

1. The frame of every electric motor shall be efficiently connected with earth.

Metal Casing.

2. The consumer's wires forming the connections to motors, or otherwise in connection with the supply, shall be, as far as practicable, completely enclosed in strong metal casing efficiently connected with earth, or they shall be fixed in such a manner that there shall be no danger of any shock.

Switches.

3. The supply to every motor shall be controlled by means of an efficient cut-off switch, placed in such a position as to be easily handled by the person in charge of the motor, and connected so that by its means all pressure can be cut off from the motor itself, and from any regulating switch, resistance or other device in connection therewith.

Protection against excess of Current, Shock, and Fire.

4. Switches, efficient fuses or other automatic circuit-breakers shall be provided so as to protect the circuits from excess of current, and all switches and cut-outs shall be so enclosed and protected that there shall be no danger of any shock being obtained in the

ordinary handling therof, or of any fire being caused by their normal or abnormal action.

5. A notice shall be fixed in a conspicuous position at every motor and switchboard in connection with the supply forbidding unauthorized persons to touch the motors or apparatus. Danger Notices.

Arc Lamps in Series.

1. The consumer's wires forming the connections to the arc lamps, or otherwise in connection with the supply, shall be, as far as practicable, completely enclosed in strong metal casing efficiently connected with earth, or they shall be fixed in such a manner that there shall be no danger of any shock. Metal Casing.

2. The supply to every arc lamp shall be controlled by means of an efficient cut-off switch, placed in such a position as to be easily handled by the person in charge of the arc lighting, and connected so that by its means all pressure can be cut off from the arc lamp itself, and from any regulating switch, resistance or other device in connection therewith. Provided that where the arc lamps are connected in series across the outer conductors of a three-wire system, it shall be sufficient if one such switch be provided for each series of arc lamps. Switches.

3. Switches, efficient fuses or other automatic cut-outs shall be provided, so as to protect the circuits from excess of current, and all switches and cut-outs shall be so enclosed and protected that there shall be no danger of any shock being obtained in the ordinary handling thereof, or of any fire being caused by their normal or abnormal action. Protection against excess of Current, Shock, and Fire.

Incandescent Lamps in Series.

1. The consumer's wires forming the connections to the incandescent lamps, or otherwise in connection with the supply, shall be completely enclosed in Metal Casing.

strong metal casing, and this casing, together with the switches and lamp holders, if metallic, shall be efficiently connected with earth.

Protection against excess of Current, Shock, and Fire.

2. Switches, efficient fuses or other automatic cut-outs shall be provided, so as to protect the circuits from excess of current, and all switches and cut-outs shall be so enclosed and protected that there shall be no danger of any shock being obtained in the ordinary handling thereof, or of any fire being caused by the normal or abnormal action.

INTERNAL WIRING OF BUILDINGS

HOME OFFICE SPECIAL RULES (1905) FOR THE INSTALLATION AND USE OF ELECTRICITY IN MINES.

[*The following rules shall be observed, as far as is reasonably practicable, in the Mine.*]

Definitions.

The expression "pressure" means the difference of electrical potential between any two conductors through which a supply of energy is given, or between any part of either conductor and earth as read by a hot wire or electrostatic volt-meter, and

(*a*) Where the conditions of the supply are such that the pressure at the terminals where electricity is used cannot exceed 250 volts, the supply shall be deemed a low-pressure supply.

(*b*) Where the conditions of supply are such that the pressure at the terminals where the electricity is used, between any two conductors, or between one conductor and earth, may at any time exceed 250 volts, but cannot exceed 650 volts, the supply shall be deemed a medium-pressure supply.

(*c*) Where the conditions of supply are such that the pressure at the terminals where the electricity is used between any two conductors, or between one conductor and earth, may at any time exceed 650 volts, but cannot exceed 3,000 volts, the supply shall be deemed a high pressure supply.

(*d*) Where the conditions of supply are such that the pressure at the terminals where the electricity is used, between any two conductors, or between one conductor and earth, may at any time exceed 3,000 volts, the supply shall be deemed an extra high-pressure supply.

INTERNAL WIRING OF BUILDINGS

Section I.

GENERAL.

1. (*a*) All electrical apparatus and conductors shall be sufficient in size and power for the work they may be called upon to do, and so far as is reasonably practicable, efficiently covered or safeguarded, and so installed, worked, and maintained as to reduce the danger through accidental shock or fire to the minimum, and shall be of such construction and so worked that the rise in temperature caused by ordinary working will not injure the insulating materials.

(*b*) In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, the covering shall be constructed so that, as far as is reasonably practicable, there is no danger of firing gas by sparking or flashing which may occur during the normal or abnormal working of the apparatus.

(*c*) All metallic coverings, armouring of cables, other than trailing cables, and the frames and bedplates of generators, transformers, and motors other than portable motors, shall, as far as is reasonably practicable, be efficiently earthed where the pressure at the terminals where the electricity is used exceeds the limits of low pressure.

2. Where a medium-pressure supply is used for power purposes, or for arc lamps in series, the wires or conductors forming the connections to the motors, transformers, arc lamps, or otherwise in connection with the supply, shall be, as far as is reasonably practicable, completely enclosed in strong armouring or metal casing efficiently connected with earth, or they shall be fixed at such a distance apart, or in such a manner, that danger from fire or shock may be reduced to the minimum. This rule shall not apply to trailing cables.

3. Where a medium-pressure supply is used for incandescent lamps in series, the wires or conductors forming connections to the incandescent lamps, or otherwise in connection with the supply, shall be, as far as is reasonably

practicable, completely enclosed in strong armouring or metal casing efficiently connected with earth, or they shall be fixed at such a distance apart, or in such a manner that danger from fire or shock shall be reduced to the minimum.

4. Motors of coal-cutting and such other portable machines shall not be used at a pressure higher than medium pressure. No transformer used for supplying current at a pressure higher than medium pressure and no motor using such current shall be of less normal rating than 20 b.h.p. for use underground.

No higher pressure than a medium pressure shall be used in any place or part of the mine to which General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies.

5. No higher pressure than a medium-pressure supply shall be used other than for transmission or for motors, and the wires or conductors other than overhead lines above ground forming the connections to the motors or transformers or otherwise in connection with the supply shall be completely enclosed in a strong armouring or metal casing efficiently connected with earth, or they shall be fixed at such a distance apart, or in such a manner that danger from fire or shock shall be reduced to the minimum.

The machines, apparatus, and lines shall be so marked as to clearly indicate that they are high pressure, either by the use of the word "Danger" at frequent intervals, or by red paint properly renewed when necessary.

6. The insulation of every complete circuit other than telephone or signal wires used for the supply of energy, including all machinery, apparatus, and devices forming part of or in connection with such circuit, shall be so maintained that the leakage current shall, so far as is reasonably practicable, not exceed $\frac{1}{1000}$ of the maximum supply current, and suitable means shall be provided for the immediate localization of leakage.

7. In every completely insulated circuit, earth or fault detectors shall be kept connected up in every generating and transforming station, to show immediately any defect in the insulation of the system. The readings of these

instruments shall be recorded daily in a book kept at the generating or transforming station or switch-house.

8. Main and distribution switch and fuse boards must be made of incombustible insulating material, such as marble or slate free from metallic veins, and be fixed in as dry a situation as practicable.

9. Every sub-circuit must be protected by a fuse on each pole. Every circuit carrying more than 5 ampères up to 125 volts or 3 ampères at any pressure above 125 volts, must be protected in one of the following alternative methods :—

(*a*) By an automatic maximum cut-out on each pole.

(*b*) By a detachable fuse on each pole, constructed in such a manner that it can be removed from a live circuit with the minimum risk of shock.

(*c*) By a switch and fuse on each pole.

10. Fire buckets, filled with clean, dry sand, shall be kept in electrical machine rooms, ready for immediate use in extinguishing fires.

No repair or cleaning of the live parts of any electrical apparatus except mere wiping or oiling shall be done when the current is on.

Gloves, mats, or shoes of indiarubber or other non-conducting material shall be supplied and used where the live parts of switches or machines working at a pressure exceeding the limits of low pressure have to be handled for the purpose of adjustment.

11. A competent person shall be on duty at the mine when the electrical apparatus or machinery is in use ; and at such time as the amount of electricity delivered down the mine exceeds 200 b.h.p., a competent person shall be on duty at the mine above ground, and another below ground. Every person appointed to work any electric apparatus shall have been instructed in his duty and be competent for the work that he is set to do.

12. No person shall wilfully damage, interfere with, or without proper authority remove or render useless any electric line or any machine, apparatus, or part thereof,

used in connection with the supply or use of electricity.

13. Instructions shall be posted up in every generating, transforming, and motor-house containing directions as to the restoration of persons suffering from electric shock.

14. Direct telephonic or other equivalent means of communication shall be provided between the surface and the pit bottom or main distributing centre in the pit.

15. Within three months after the introduction into any mine of electric motive power, notice in writing must be sent to H.M. Inspector of Mines for the district. Notice must also be sent of any existing electric motive-power installation at any mine within three months after the coming into force of these rules.

16. A plan shall be kept at the mine showing the position of all permanent electrical machinery and cables in the mine, and shall be corrected as often as may be necessary to keep it up to a date not more than three months previously.

Section II.

GENERATING STATIONS AND MACHINE ROOMS.

17. Where the generating station under the control of the owner or manager of the mine is not within 400 yards of the working pit mouth, an efficiently enclosed locked switch box or boxes, or a switch-house, shall, where reasonably practicable, be provided near the pit mouth, for cutting off the supply of electricity to the mine.

18. There shall be a passage way in front of the switchboard of not less than 3 ft. in width, and if there are any connections at the back of the switchboard, any passage way behind the switchboard shall not be less than 3 ft. clear. This space shall not be utilized as a storeroom or a lumber room, or obstructed in any manner by resistance frames, meters, or otherwise. If space is required for resistance frames or other electrical apparatus behind the board, the passage way must be widened accordingly.

No cable shall cross the passage way at the back of the

board except below the floor, or at a height of not less than 7 ft. above the floor.

The space at the back of the switchboards shall be properly floored, accessible from each end, and, except in the case of low-pressure switchboards, must be kept locked up, but the lock must allow of the door being opened from the inside without the use of a key. The floor at the back shall be incombustible, firm and even.

19. Every generator shall be provided with a switch on each pole between the generator and the bus-bars.

When continuous-current generators are paralleled reserved current cut-outs shall also be provided.

Suitable instruments shall be provided for measuring the current and pressure of each generator.

Every feeder circuit shall at its origin be provided with an ammeter.

20. If the transmission lines from the generating station to the pit are overhead there shall be lightning arresters in connection with the feeder circuits.

21. Automatic cut-outs must be arranged so that when the contact lever opens outwards no danger exists of striking the head of the attendant. If unenclosed fuses are used they must be placed within 2 ft. of the floor, or be otherwise suitably protected.

Where the supply is at a pressure exceeding the limits of medium pressure, there shall be no live metal work on the front of the main switchboard within 8 ft. of the floor or platform, and the space provided under Rule No. 2 of this section shall be not less than 4 ft. in the clear. Insulating floors or mats shall be provided for medium-pressure boards where live metal work is on the front or back.

22. All terminals and live metal on machines over medium pressure above ground, and over low pressure under ground, where practicable shall be protected with insulating covers or with metal covers connected to earth.

23. No person other than an authorized person shall enter a machine or motor room, or interfere with the working of any machine, motor, or apparatus connected therewith.

INTERNAL WIRING OF BUILDINGS

Section III.

CABLES.

24. All conductors (except as hereinafter provided) shall in every case be maintained completely insulated from earth, but it is permissible to use the concentric system with earthed outer conductor, if proper arrangements are made to reduce the danger from fire or shock to the minimum, but the neutral point of polyphase systems and the middle wire of three-wire continuous-current systems may be earthed at one point.

25. Unless fixed as far as is reasonably practicable out of reach of injury, all conductors, other than armoured cables, must further be protected by a suitable covering. Where lead-covered cable is used the lead shall be earthed, and electrically continuous throughout.

The exposed ends of cables where they enter the terminals of switches, fuses and other appliances, must as far as is reasonably practicable be properly protected and finished off, so that moisture cannot creep along the insulating material within the waterproof sheath, nor can the insulating material, if of an oily nature, leak out of the cable.

26. All joints must be mechanically and electrically efficient, and, where reasonably practicable, must be suitably soldered. In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, suitable joint boxes must be used, and the conductors connected by means of metal screw clamps, connectors, or their equivalent constructed in a safe manner. Provided that in any place or part of a mine where a shot may be fired joints may be soldered by or in the presence of a person authorized in that behalf by the manager, but the same precautions in regard to examination and removal of workmen as are prescribed by paragraphs (*f*) and (*i*) of General Rule 12 shall be observed in all cases, and where the place is dry and dusty, also the precautions as to watering prescribed by paragraph (*h*). Wires, other than signalling wires, or cables must not be joined by merely twisting them together.

27. Overhead bare wires on the surface must be efficiently supported upon insulators, and clear of any traffic, and provided with efficient lightning arresters.

28. All cables used in shafts must be highly insulated and substantially fixed. Shaft cables, not capable of sustaining their own weight, shall be properly supported at intervals varying according to the weight of the cable. Where the cables are not completely boxed in and protected from falling material, space shall be left between them and the side of the shaft that they may yield, and so lessen a blow given by falling material.

29. Where the cables in main haulage roads cannot be kept at least 1 foot from any part of the tub or tram, they shall be specially protected. When separate cables are used they shall, if reasonably practicable, be fixed on opposite sides of the road.

The fixing with metallic fastenings of cables and wires not provided with metallic covering to walls or timbers is prohibited.

Cables underground when suspended shall be suspended by leather or other flexible material in such a manner as to allow of their readily breaking away when struck, before the cables themselves can be seriously damaged.

Where main or other roads are being repaired, or blasting is being carried out, suitable temporary protection must be used so that the cables are reasonably protected from damage.

30. Trailing cables for portable machines shall be specially flexible, heavily insulated and protected with either galvanized steel wire armouring, extra stout braiding, hose pipe, or other effective covering. Trailing cables shall be examined at least once in each shift by the person in charge of the machine, and any defects in them promptly repaired.

At points where the flexible conductors are joined to the main cables, a fixed terminal box must be provided, and a switch shall be fixed close to or in the terminal box capable of entirely cutting off the supply from the terminal box and motor.

INTERNAL WIRING OF BUILDINGS

Section IV.

SWITCHES, FUSES, AND CUT-OUTS.

31. Fuses and automatic cut-outs shall be so constructed as effectually to interrupt the current when a short circuit occurs, or when the current through them exceeds the working current by 200 per cent. Fuses shall be stamped or marked, or shall have a label attached, indicating the current with which they are intended to be used, or where fuse wire is used each coil in use shall be so stamped or labelled. Fuses shall only be adjusted or replaced by an authorized person.

32. All live parts of switches, fuses, and cut-outs not in machine rooms, or in compartments specially arranged for the purpose, must be covered. These covers must be of incombustible material, and must be either non-conducting or of rigid metal, and, as far as practicable, clear of all internal mechanism.

33. All points at which a circuit other than those for signals has to be made or broken shall be fitted with proper switches. The use of hooks or other makeshifts is prohibited, and in any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, the use of open-type switches, fuses, and cut-outs is prohibited; they must either be enclosed in gas-tight boxes, or break under oil.

Section V

MOTORS.

34. All motors, together with their starting resistances, shall be protected by switches capable of entirely cutting off the pressure, and fixed in a convenient position near the motor, and every motor of 10 b.h.p. or over in a machine room underground shall be provided with a suitable ammeter to indicate the load put upon the machine.

35. Where unarmoured cables or wires pass through metal frames or into boxes or motor casings, the holes

must be substantially bushed with insulating bushes, and, where necessary, with gas-tight bushings which cannot readily become displaced.

36. Terminal boxes of portable motors must be securely attached to the machine, or be designed to form a part thereof.

37. In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, all motors, unless placed in such rooms as are separately ventilated with intake air, shall have all their current-carrying parts, also their starters, terminals, and connections completely enclosed in flame-tight enclosures, made of uninflammable material and of sufficient strength as not to be liable to be damaged should an explosion of firedamp occur in the interior, and such enclosures shall not be opened except by an authorized person, and then only when the current is switched off. The pressure shall not be switched on while the enclosures are open.

38. In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, a safety lamp or other suitable apparatus for the detection of firedamp shall be provided for use with each machine when working, and should any indication of firedamp appear on the flame of the safety lamp or other apparatus used for the detection of firedamp, the person in charge shall immediately stop the machine, cut off the current at the gate end or nearest switch, and report the matter to an official of the mine.

39. (*a*) A coal-cutter motor shall not be kept continuously at work for a period of time exceeding a maximum period which shall be specified in writing by the manager, so that the roof may be carefully examined.

(*b*) The casing or inspector doors of all portable motors used underground and the casings of their switches and other appliances shall at least once a week be opened by a manager, and the parts so disclosed shall be cleaned and examined before the coverings are replaced. In special cases requiring a motor to run continuously longer than

one week, the motor shall be examined at the end of the run. A report of such examination shall be entered in a report book.

40. The person in charge of a coal-cutter or drilling machine shall not leave the machine while it is working, and shall, before leaving the working place, see that the current is cut off from the trailing cables. He must not allow the cables to be dragged along by the machine. No repairs shall be made to any portable machine until the pressure has been cut off from the trailing cables.

41. If any electric sparking or arc be produced outside a coal-cutting or other portable motor or by the cables or rails, the machine shall be stopped, and not be worked again until the defect is repaired, and the occurrence shall be reported to an official of the mine.

Section VI.

ELECTRIC LOCOMOTIVES.

42. Electric haulage by locomotives by the trolley wire system is not permissible in any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies. On this system no pressure exceeding the limits of medium pressure may be employed.

43. In underground roads the trolley wires must be placed so that they are at least 7 ft. above the level of the road or track, or elsewhere, if sufficiently guarded, or the pressure must be cut off from the wires during such hours as the roads are used for travelling on foot in places where trolley wires are fixed. The hours during which travelling on foot is permitted shall be clearly indicated by notices and signals placed in a conspicuous position at the ends of the roads. At other times no one other than a duly authorized person shall be permitted to travel on foot along the road.

On this system either insulated returns or uninsulated metallic returns of low resistance may be employed.

44. In order to prevent any other part of the system being earthed (except when the concentric system with earthed outer conductor is used), the current supplied for use on the trolley wires with an uninsulated return shall be generated by a separate machine, and shall not be taken from or be in connection with electric lines otherwise completely insulated from earth.

45. If storage battery locomotives are used in any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, the rules applying to motors in such places shall also be deemed to apply to the boxes containing the cells.

Section VII.

ELECTRIC LIGHTING.

46. All arc lamps shall be so guarded as to prevent pieces of ignited carbon falling from them, and shall not be used in situations where there is likely to be danger from the presence of coal-dust. They should be so screened as to prevent risk of contact with persons.

47. Small wires for lighting circuits must be either conveyed in pipes or casings, or suspended from porcelain insulators, or tied to them with some non-conducting material which will not cut the covering, and so that they do not touch any timbering or metal work. On no account must staples be used. If metallic pipes are used they must be electrically continuous and earthed. If separate uncased wires are used they must be kept at least 2 in. apart, and not brought together except at lamps or switches or fittings.

48. In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, electrical lamps, if used, must be of the vacuum or enclosed type; they shall be protected by gas-tight fittings of strong glass, and have no flexible cord connections, and shall only be changed by a duly authorized competent person. While the lamps are being changed the current shall be switched off.

49. In all machine rooms and other places underground, where a failure of electric light is likely to cause danger, some safety lamps, or other proper lights, shall be kept for use in the event of such failure.

Section VIII.

SHOT-FIRING.

50. Electricity from lighting or power cables shall not be used for firing shots, except in sinking shafts or stone drifts, and then only when a special firing plug, button, or switch is provided, which plug, button, or switch shall be placed in a fixed locked box, and shall only be accessible to the authorized shot-firer.

The firing cables or wires shall not be connected to this box until immediately before it is required for the firing of shots, and shall be disconnected immediately after the shots are fired.

When shot-firing cables or wires are used in the vicinity of power or lighting cables, sufficient precautions shall be taken to prevent the shot-firing cables or wires from coming in contact with the lighting or power cables.

The foregoing rules shall not apply to telephone, telegraph, and signal wires, to which the rules of this section only shall apply.

Section IX.

SIGNALLING.

51. All proper precautions must be taken to prevent electric signal and telephone wires from coming into contact with other electric conductors, whether insulated or not.

52. Contact makers or push buttons of electric signalling circuits shall be so constructed and placed as to prevent the circuit being accidentally closed.

53. In any place or part of a mine where General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, bare wires shall not be used for signalling circuits except in

haulage roads, and the pressure shall not exceed 15 volts in any one circuit.

SECTION X.

ELECTRIC RELIGHTING OF SAFETY LAMPS.

54. In mines to any place or part of which General Rule No. 8 of the Coal Mines Regulation Act, 1887, applies, when safety lamps are relighted underground by electricity, the manager shall select a suitable station or stations, which are not in the return airway, and in which there is not likely to be any accumulation of inflammable gas ; and no electric relighting apparatus shall be used in any other place. All electrical relighting apparatus shall be securely locked, so as not to be available for use except by persons authorized by the manager to relight safety lamps, and such persons shall examine all safety lamps brought for relighting before they are re-issued.

SECTION XI.

EXEMPTIONS AND MISCELLANEOUS.

55. Notwithstanding anything contained in these rules any electrical plant or apparatus installed or in use before the coming into force of these rules may be continued in use unless an inspector shall otherwise direct, or subject to any conditions affecting safety that he may prescribe.

In case any difference of opinion shall arise between an inspector and an owner under this Rule, the same shall be settled as provided in section 42 of the Coal Mines Regulation Act, 1887.

56. Any of the foregoing requirements shall not apply in any case in which exemption is obtained from the Secretary of State, on the ground either of emergency or special circumstances, on such conditions as the Sercetary of State may prescribe.

RULES AS TO TESTING ELECTRICITY METERS, ETC., AND SCALES OF FEES PRESCRIBED BY THE LONDON COUNTY COUNCIL ON MARCH 29, 1898, AND APPROVED BY THE BOARD OF TRADE ON JUNE 17 FOLLOWING.

METERS IN USE UPON A CONSUMER'S PREMISES.

(1) Upon any application being received by the Council in connection with any difference arising between any consumer and the undertakers as to the accuracy of any meter, an appointment will be made with the consumer and the undertakers for an inspector to attend at the premises of the consumer. The inspector will take charge of the meter, which is not to be disconnected from the circuit except in his presence, and then only by the undertakers.

(2) The inspector will, as far as possible, ascertain before such disconnection takes place whether the meter is properly fixed and connected with the circuit, and whether it appears to be in good working order.

(3) If the meter be not one requiring to be tested for synchronism, it will then be removed under the supervision of the inspector to the Council's office, 42, Cranbourne Street, to be there tested for accuracy.

(4) If the meter be of a type requiring to be tested for synchronism, it will, if necessary after disconnection from the circuit, and before removal from its position, be sealed up by the inspector and run for at least 24 hours without current being allowed to pass through the main coils, and at the end of that time or of such longer time as may be convenient, the result will be ascertained by the inspector and the meter then removed in the manner before indicated.

(5) Before removing the meter, the inspector will ascertain as accurately as possible the total current which may be taken

if all the current-consuming devices connected with the installation are put on to the circuit, and also the average and the maximum normal current.

(6) If the inspector considers it desirable, he will also, with the concurrence of the applicant and upon payment of the prescribed fee, test the insulation resistance of the meter as fixed, and of the house installation connected therewith.

(7) In the case of meters which can, under certain circumstances, register without current passing through the main coils, the inspector will make a careful examination to ascertain whether such registration is effected.

(8) The tests for accuracy will be made at the Council's meter-testing station, 42, Cranbourne Street.

(9) In the case of meters which before being fixed shall have been tested by the Council and passed as correct meters, the meters will be tested for starting current and at one or more quarter loads, and if the results be approximately the same as those obtained in the previous tests the meters will be considered correct. (A meter shall be considered to be "correct" when the registration shown by the dials is within 2½ per cent. of absolute accuracy at all points above one-twentieth load.)

(10) In the case of meters which have not been tested and sealed by the Council before fixing, the tests will be made at the average load used by the consumer, if this can be ascertained.

(11) In cases where the meter has been removed from the consumer's premises before any application for testing is made to the Council, it may nevertheless be tested for accuracy, but a note will be attached to the report stating that the meter was removed from the consumer's premises before it was tested, and that the Council has no means of ascertaining whether its condition is the same as it was when so fixed.

(12) At least one test will be made of every meter by a dial reading, and the dial works will be further examined to ascertain that the gearing is properly proportioned.

(13) The report of the inspector, or a copy thereof, will be sent both to the consumer and to the undertakers by the engineer in charge of the Council's meter-testing station.

(14) All fees for testing shall, unless the Council otherwise

order, be paid in advance by the applicant to the cashier of the Council at its office in Spring Gardens.

(15) Within one week after the completion of the test the meter will be handed at Cranbourne Street to the representative of the owner, unless circumstances shall have arisen which render a further test desirable.

(16) For all meters of a pattern approved by the Board of Trade, any recommendations made by that Board with regard to testing will be followed so far as circumstances admit.

SCALE OF FEES FOR TESTING ELECTRICITY METERS, ETC.

SINGLE OR DISPUTED METERS

(used or to be used in any district for which the Council is the statutory authority).

For testing a single meter *of any description* up to 50 ampères capacity, 10*s*.

For testing a single meter of capacity from 50 to 100 ampères, 20*s*.

For testing a single meter of capacity from 100 to 200 ampères, 25*s*.

For testing a single meter of capacity from 200 to 400 ampères, 30*s*.

For testing each "disputed" meter the charge shall be as above, and no reduction shall be made if a number of disputed meters be sent in together.

BATCHES OF METERS.

For testing meters, delivered at and removed from the testing-station free of cost to the Council, any work necessary for adjusting inaccurate or defective meters being charged for extra—

Class 1.—Meters without shunt coils and not requiring to be fixed for testing, up to 50 ampères capacity, if sent in in batches of not fewer than 10 of the same size and make, each 6*s*. 6*d*.

Ditto, from 50 to 100 ampères capacity, each 9*s*.

Ditto, from 100 to 200 ampères capacity, each 12*s*.

Class 2.—Meters with shunt coils or requiring to be fixed for testing, up to 50 ampères capacity, if sent in in batches of not less than 10 of the same size and make, each 7*s*.

Ditto, from 50 to 100 ampères capacity, each 10*s*.

Ditto from 100 to 200 ampères capacity, each 13*s*.

Class 3.—Meters requiring fixing and synchronising, or adjusting after fixing, up to 50 ampères capacity, if sent in in batches of not less than 10 of the same size and make, each 8*s*.

Ditto, from 50 to 100 ampères capacity, each 12*s*.

Ditto, from 100 to 200 ampères capacity, each 17*s*. 6*d*.

Class 4.—Meters for multiple circuits will be charged for according to the number of circuits.

Class 5.—Meters which require to be tested on a circuit absorbing considerable power will be charged for at special rates.

A reduction of 10 *per cent. from these prices to be allowed when* 20, *and of* 25 *per cent. when* 50, *meters of the same make and capacity are sent in at the same time.*

Partial re-tests made on any meter after adjustment will be charged, according to amount of work involved, at one-fourth to one-half of the fee charged for "single or disputed" meters of the same capacity.

Inspection in situ.

For examining in position after fixing, and certifying if found correct, any single meter (which has already been tested for accuracy at the Council's testing-station) within a radius of three miles from Cranbourne Street, 2*s*. 6*d*.

Ditto, any distance from three to six miles, 3*s*. 6*d*.

For examining in position after fixing, where a number of meters in the same district, and within a reasonable distance of each other can be inspected on the same day, £1 for the services of the inspector for the entire day, or 15*s*. for half a day. A further charge of 6*d*. will be made for each certificate.

INTERNAL WIRING OF BUILDINGS

Electric Pressure.

For taking a record of "pressure" at any consumer's house within three miles of the testing-station, such record extending over 24 hours, 10*s*. 6*d*.

If such record extends over two or more consecutive periods of 24 hours, for each succeeding period, 5*s*.

Service Lines.

For testing a single pair of service lines, 10*s*.

In difficult cases (in addition to the fee of 10*s*.), for every hour or part of an hour occupied after the first two hours, 5*s*.

For testing any installation for insulation resistance to earth, where the time occupied is less than two hours, 10*s*.

For every hour or part of an hour after the first two hours, 5*s*.

Note.—*The above fees are to include omnibus fare for the inspector and assistant, but all other travelling expenses and cost of carriage of meters, etc. (if any) to be charged in addition.*

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